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**Proceedings of the
First International Conference on
Alternative Aviation Fuels**

May 1996

Final Report

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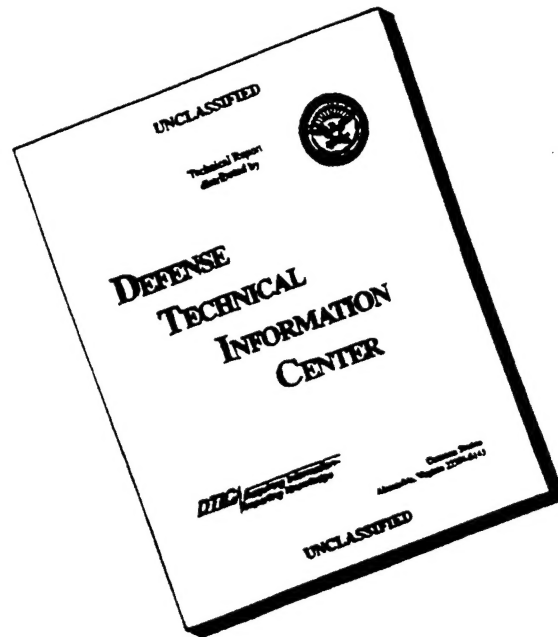
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| 16. Abstract Baylor University, in conjunction with the U.S. Department of Energy (DOE), Federal Aviation Administration (FAA), and Texas State Technical College presented the First International Conference on Alternative Aviation Fuels to introduce members of the industry to the promise and applications of alternative fuels in aviation. Topics covered in the papers and panels included: <ul style="list-style-type: none"> • Environmental impact of alternative aviation fuels • Cost-effectiveness and characteristics of alternative fuels • Alternative aviation fuel case studies • Fuel suppliers' and manufacturers' responses to alternative fuels • Barriers to commercialization of the technology The conference also included a Certification Procedure Workshop to provide insight into the process, procedures, and flight standards associated with alternative aviation fuels. | | | |
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PROCEEDINGS OF THE FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE AVIATION FUELS NOVEMBER 2-4 1995 BAYLOR UNIVERSITY

TABLE OF CONTENTS

| | |
|--|--|
| Executive Summary | |
| Welcoming Remarks | Thomas Daschle, U.S. Senate Robert Sloan, Baylor University |
| Opening Remarks | John Russell, U.S. Department of Energy |
| Address at Opening Reception | William Wells, Delta-T Corporation Linda Ethridge, Mayor ProTem of Waco* |
| Keynote and General Overview | Paul MacCready, AeroVironment |
| Workshop on Certification Procedures | Gus Ferrara, Independent Aviation Consultant Paul Pendleton, Federal Aviation Administration* |
| Strategy session - Commercializing Alternative Fuels on the Aviation Sector - Panel Summary | Bill Holmberg, American Biofuels Association (Facilitator) Max Shauck, Baylor University Gus Ferrara, Independent Aviation Consultant John Russell, U.S. Department of Energy Russel Smith, Texas Renewable Energy Industry Association Clay Wilkins, Texas State Technical College Phil Lampert, National Ethanol Vehicle Coalition |
| Developments in Aviation Fuel Properties | Brent Bailey, National Renewable Energy Laboratory |
| Aviation Gasoline Situation: Current Search for Petroleum Alternatives to Av-Gas | Doug Macnair, Aircraft Owners & Pilots Association |
| Fuel Suppliers' Response to Alternative Fuels Panel Summary | Todd Sneller, Nebraska Ethanol Board (Facilitator) Fred Potter, Information Resources, Inc. Chuck Minard, Conoco, Inc. Richard Riley, Phillips Petroleum Company Jerrel Branson, Ecogas Corporation |

Manufacturers' Response to Alternative Fuels

Barrett Productions Aircraft:
Cessna Aircraft:

Luncheon Address

Renewable Aviation Fuels Development Center

Experience with Methanol-Powered Aircraft

Worldwide Alternative Fuel Experiences

Brazil:
Europe:
France:
Italy:
United Nations:
Experimental Aircraft Association:

Conference Summary

Address at Evening Reception
Clean Airports Criteria

Conference Registration Listing

Conference Speaker Information

* no written materials

Jim Johnson, Wisconsin State Agency Services
(Facilitator)*

Monty Barrett, Barrett Production Aircraft
Cesar Gonzalez, Cessna Aircraft Company

Garry Mauro, Texas General Land Office

Max Shauck, Baylor University

Gordon Cooper, Galaxy Aerospace Management

Paul MacCready, AeroVironment (Facilitator)*
Plinio Nastari, DataGro, Ltd.
Mats Ekelund, Crossroad Consultants, Ltd.
Phillipe de Segovia, *Aviation & Pilote* Magazine
Mauro Furlan, Italian Ultra-Light Ethanol Project
George Papadatos, United Nations
Earl Lawrence, Experimental Aircraft Association

Robert Harris, Nebraska State Energy Office

Andres Zellweger, Federal Aviation Administration

EXECUTIVE SUMMARY

On November 2, 1995, people from around the world gathered in Waco, Texas at Baylor University for the "First International Conference on Alternative Aviation Fuels." Over 100 people from seven countries and three continents were present to listen to researchers, representatives of industry, pilot organizations and the U.S. Government as they discussed the need to find a replacement for 100-octane leaded aviation gasoline and the promise held by alternative aviation fuels.

The conference represented all points of view. From pioneers in the use of alcohol fuels in aircraft, such as Mercury Astronaut Gordon Cooper and Baylor Professor Max Shauck, to people, such as Cessna's Cesar Gonzalez, who are convinced that the future of general aviation is inextricably tied to the petroleum industry, there was someone representing every possible viewpoint at the conference.

In order to encourage the exchange of viewpoints the conference organizers made deliberate use of informal settings, such as Waco's famous Doctor Pepper Museum, to allow the conference attendees to relax and to get to know each other. As a result, there was frank discussion of the differing viewpoints held by the conference attendees.

While on some points people agreed to disagree, there were a number of areas of wide agreement. First and foremost among these was the consensus that the days of leaded Avgas are limited. Everyone agreed that either as a result of government regulation or as a result of unfavorable economics, in the near future, fuel producers are not going to be able or willing to continue to supply leaded Avgas.

There was much discussion of the different advantages and disadvantages associated with the fuels offered as alternatives to leaded Avgas. The renewable fuels advocates pointed out that renewable aviation fuels, such as ethanol and ETBE, have very good anti-knock characteristics, are much less prone to vapor lock and have broad ranging economic and environmental benefits for society. Proponents of other fuels, pointed out that these fuels have problems with range and the lack of existing infrastructure.

Representatives of the EAA, AOPA and Cessna pointed out the size of the aviation fuels market is very small and therefore concluded that the future of aviation fuels should be tied to existing larger fuels markets. These people argued in favor of using Autogas in aircraft or developing a fuel, such as 82UL, that has characteristics very close to existing unleaded motor gasolines. Opponents of this viewpoint, noted the technical and economic difficulties of developing a high octane aviation fuel derived from petroleum and the fact that the majority of Avgas is used by aircraft that are unable to use a low octane fuel. They also pointed out that if the aviation community does not take advantage of the opportunities offered by the need to find an alternative to leaded Avgas, then it will be passing up a unique chance to make flying more economically and environmentally beneficial to the nation.

The conclusion of the conference was a trip to Texas State Technical College where Baylor's Renewable Aviation Fuels Development Center conducts engine tests, aircraft modification, maintenance, and flight testing. Conference attendees were able to inspect Baylor's collection of four ethanol powered aircraft and the aircraft of the Vanguard Squadron. They were also treated to an ethanol-powered airshow by the Vanguard Squadron in their four RV-3's and Max Shauck in his Pitts S-2B.

The goals of the conference were to exchange information, encourage open debate between opposing viewpoints and, hopefully, stimulate new research and development of alternative aviation fuels. All of these goals were achieved.

BAYLOR

U N I V E R S I T Y

Dear Colleague:

Thank you for attending the "First International Conference on Alternative Aviation Fuels" held in Waco, Texas, on November 2-4. Your participation made an important contribution to its success.

I hope that the conference was an informative and enjoyable experience for you and I hope that you will also find these proceedings to be useful.

A multiplicity of views, both pro and con, were expressed by the conference's international panel of speakers. This document contains the accumulated papers, and other materials, provided to us by them. Where no materials were provided to us by a speaker, we have attempted to accurately summarize their remarks made during the conference.

It is my hope that this was merely the first of a series of conferences -- which will continue until the need for them disappears because of the successful commercialization of alternative fuels in aviation. For that reason, I extend to you my best wishes until we meet again.

Sincerely,



Max Shauck, Chairman
Baylor Department of Aviation Sciences

WELCOMING REMARKS

HONORABLE TOM DASCHLE
SOUTH DAKOTA SENATOR
UNITED STATES SENATE

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

STATEMENT OF TOM DASCHLE
BAYLOR CONFERENCE ON ALTERNATIVE AVIATION FUELS

As a pilot and ethanol advocate of longstanding, I am doubly pleased to join you today at the Baylor Conference where much needed discussion is taking place over the most fruitful ways to commercialize alternative aviation fuels.

However, before I get started talking about the exciting prospects for the use of ethanol and ETBE as aviation fuel, I want to take a moment to express my appreciation to Max Shauck for inviting me to speak to you and for all his efforts to build public acceptance of alternative aviation fuels.

Max deserves tremendous credit both for this conference and for his work over the years researching and championing the use of these fuels in aviation.

Not only has Max made great strides in advancing the scientific and technical case for using alternative fuels in aviation, he has done it with great flair and style, giving all of us a genuine thrill with his outstanding stunt flying.

Max's skill as demonstrated at the Ethanol Air Show in my home town of Aberdeen, South Dakota, is legendary. And I can personally attest to his ability as a pilot, having been foolhardy enough to ride with him at this event.

As you all know, across the country more and more pilots are expressing enthusiasm for ethanol and ETBE as an aviation fuel, and air shows and conferences like this are showcasing its potential for wider-scale use. Nowhere is the leadership of this movement more notable than in my home state of South Dakota, where every year the enthusiasm grows and finds expression in local air shows.

The air shows have certainly helped to popularize the notion that ethanol and ETBE can and should be used as aviation fuels.

Seminars are given to teach pilots and mechanics about the use of ethanol as an aviation fuel. And pilots demonstrate to the public how safe and effective ethanol is for flying.

These are critical steps in the growth of this industry. But it will be at the

conferences like this one where the real strategy will emerge that ultimately will lead to widespread success.

Today, alternative fuels like ethanol offer the nation a great opportunity to become more independent in meeting our energy needs, to increase farm income, to create American jobs, and to clean up our air. And through public demonstration, the nation is learning these lessons -- lessons that we in South Dakota have known for years.

This past year the effort to promote the domestic renewable fuels industry as an objective of public policy has had its ups and downs. But despite some setbacks, progress in expanding the use of ethanol in automobile fuel has been made.

The Clinton Administration clearly now is committed to promoting ethanol and has demonstrated that commitment time and time again.

I wish that I could say the same thing about all my colleagues in Congress.

Last year, EPA developed the renewable oxygen requirement for the reformulated gasoline program, requiring that 30% of the oxygenated fuel used in the program be renewable -- that meant ethanol.

When that rule was struck down by the courts, the Administration went back and petitioned for a rehearing.

Then, the EPA committed to lift the oxygen cap to allow more ethanol to be blended in each gallon of gasoline.

The EPA also is developing a model pump labelling program, so that concerned and knowledgeable consumers can know what oxygenates are used in gasoline and select ethanol or ETBE over MTBE.

Finally, the Treasury Department issued a rule on ETBE which is expected to increase ethanol demand by as much as 300 million gallons per year, making up for much of the ground lost as a result of the recent court decision.

All of these steps will help increase the use of ethanol in automobiles.

Our next challenge is to promote wide scale commercial use of ethanol as an aviation fuel.

American pilots are developing a keen interest in the potential of ethanol as aviation fuel. I fully anticipate that, in the future, the aviation industry will embrace ethanol on a large scale.

Ethanol represents a positive choice. In the future, American pilots will be able to choose to support American industry and American farmers, rather than foreign oil companies. And when an idea is this good, it develops a force of its own, compelling interest and support.

The federal government has seen the wisdom of giving ethanol production some additional encouragement, because it is sound environmental policy, sound farm policy and sound national energy policy.

I am hopeful that with some additional education, ethanol can play a major role in the half-a-billion gallon per year piston engine aviation fuel market.

In our efforts to convince more Americans that ethanol represents a sound choice for aviation fuel, it is crucial that we not only develop the sound technical record to support widespread use of ethanol in aviation, but also promote that goal with education, air show demonstrations, and well thought-out strategies for consistently expanding the use of ethanol and ETBE in the aviation fuel market.

Given the expected cuts in farm programs, and the impact those cuts will have on farm income, it is more critical than ever that we succeed in developing these new markets for ethanol.

The ongoing efforts of this conference and future conferences will go a long way toward confirming for the rest of the country the practical benefits of this fuel.

If we succeed in accomplishing our goal, it will be due in large part to the pioneering efforts of the people like Max Shauck who have exhibited the vision, energy and imagination to set us on such an important and potentially fruitful course.

So again, thank you for coming, and enjoy the conference. You are helping to shape the future.

WELCOMING REMARKS

**ROBERT SLOAN
PRESIDENT
BAYLOR UNIVERSITY**

**FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY**

Welcome Address from President of Baylor University
Dr. Robert B. Sloan

It is good to be here to offer just a couple of words of welcome to you. And, to wish you all the best as you have been here -- many of you already, before the conference -- and as you still have hours today and tomorrow ahead of you for this conference on alternative aviation fuels.

You may ask what in the world is Baylor University -- a Baptist, Christian university -- doing sponsoring, being one of the sponsors, for such an exotic conference as this. Well, let me remind you that some of you have the same kind of reputation as our founder.

I noticed today in the newspaper that it says, "Pilots, aircraft designers and experts on alternative fuels." It said are going to be at Baylor University today. Well, I think probably under our breath we could also have added, "plus a few eccentrics, cranks and crackpots."

Now, I noticed that several of you smiled broadly, and that at least one person snarled. And, I suppose that is because you are used to feeling that kind of remark from people all too often. Let me remind you that is what was said of our lord, by no less than members of his own family, that, "he has lost his mind." Now, I don't commend to you the end of Jesus' public career. Though, some of you may well have felt like that was the end towards which you were driving professionally as you have continued down through the years (I know that Max has felt like this) to beat your heads against the wall trying to get people to listen to what really is a very good idea. In fact a set of revolutionary ideas.

But, you are truly pioneers. You are people who have the force of, not only of some good moral qualities to what you want to do in terms of the earth, but you have force of great ideas. Now of course you have your opponents. You have those who, for reasons of economic interest, are not all that interested in hearing what you have to say. But we welcome you here to Baylor University because we believe in the truth. We believe that all truth is God's truth. We believe that the truth can be freely discovered and discussed. We believe that conferences such as this are the kind of thing whereby the truth gets liberated.

You are working on a wonderful set of ideas and we commend you, we encourage you, and we welcome you to the campus. Thank you for all that you do for your industries. Thank you for what you do for education. Thank you for challenging -- not only for academic institutions and not only for industries. But, thank you for the kind of brave and pioneering spirit you exhibit by being willing to think in ways that are absolutely outside the box of the established orthodoxies.

We are glad you are here at Baylor University and wish you a wonderful time.

OPENING REMARKS

JOHN RUSSELL
DIRECTOR, OFFICE OF ALTERNATIVE FUELS
U.S. DEPARTMENT OF ENERGY

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

John Russell
Director, Office of Alternative Fuels
U. S. Department of Energy
Opening Remarks

First I would like to thank Max Shauck and Baylor University for agreeing to host the first ever conference on this subject. In addition, I would like to thank TSTC (Texas State Technical College), the FAA (Federal Aviation Administration) and the great myriad of sponsors. We have people here from Italy, Brazil, France, Swede and Greece. All-in-all, we are a pretty good cross section of people who fly and work on little air planes.

Its All About Change

As Batman said to the Joker, "Things change." High-octane, low-lead, aviation gasoline, better known as 100LL, is over \$2.00 per gallon in the United States and \$5.00 per gallon in some parts of Europe. In about two years, the U.S. Environmental Protection Agency is going to banish TEL (tetra-ethyl-lead) form Avgas (aviation gasoline). This will kill about ten octane points, and you will notice it at altitude.

Alternative fuels are all about change. Every 100 years or so, we seem to change our basic mode of transport and our fuels. We are either overtaken by events and forced to change or (rarely) we elect to change in favor of a better mouse trap.

The EAA's (Experimental Aviation Association) Autogas program is a very good example of both. EAA showed great initiative in responding to the need for safety using Autogas. As a result many light aircraft now operate legally, economically and safely with Autogas.

It is a good start, but we can do even more! In fact, it is already being done. A great deal of truly pioneering work is going on right now, here at Baylor, under Max's leadership. However, the questions remain:

- Is it safe?
- Is it clean?
- Does it make good business sense?

These questions are aircraft specific and engine specific. They must be satisfied for each STC combination. I know this is heresy coming from a Washington bureaucrat, but the free market *will* and *should* determine any product's ultimate fate -- AFTER flight safety criteria are met.

Oil: A Tough Act to Follow

Following oil into the fuels market is like following George Burns onto the stage. Jet A, 100LL, reformulated gasoline, and clean diesel are excellent fuels. Their infrastructure is global. Exploration, drilling, refining, pipeline distribution and marketing are routine. There is only one catch -- a limited 50-year supply of known reserves!

Students, in particular, should consider this, because **you will be flying 50 years from now**. If you are lucky, you will be flying a Fleet, Stearman, or a J-3. They are well over 50 years old now. Consider the flying careers of jimmy Doolittle, Charles Lindbergh, Chuck Yeager, and Paul Poberezny. Our beloved Steve Wittman left us just this year after flying and racing for 71 of his 91 year. However, if supplies are only expected to last 50 years at current consumption rates, what fuel will you be using? In all likelihood, you will be using what are now considered "alternative fuels." Depend on it!

The transition to non-petroleum fuels is not going to happen overnight, and there will be many hurdles to face. This conference and all of us here today are helping to lay the foundation for alternative fuels.

Keynote Introduction

Well, yesterday you heard a lot about the trials and tribulations of certification and commercialization. Tomorrow you will go down to the flight line and see the hardware. If you are lucky you can talk somebody into a ride. Today you are going to hear about the real world situation from people who have to deal with it right now. These people are professionals. They adapt. They invent. They are ingenious. Which is not a bad description of your keynote speaker. He designed and made happen:

| | |
|--------------------|--------------|
| Gossamer Condor | Pterodactyl |
| Gossamer Albatross | GM Sunraycer |
| Solar Challenger | GM Impact EV |

As a direct result, he holds

ASME Engineer of the Century Gold Medal
Lindbergh Award
The Collier Trophy

He is a world champion glider pilot and has set numerous world records over the years. I think you will agree that his credentials are quite in order. He does not know this, but after this session I want his autograph. It is a privilege to introduce the president of AeroVironment, Dr. Paul MacCready.

ADDRESS AT OPENING RECEPTION

**WILLIAM WELLS III
VICE PRESIDENT OF MARKETING
DELTA-T CORPORATION**

**FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY**

Address at the Opening Reception

A man on the plane today saw that I was looking at my notes for this presentation. I was nervous about my talk and somewhat dissatisfied. He said, "Ad lib; usually at these things, the speaker knows the subject best. That's why they're there." Basically, he was saying the audience probably would not know if I was wrong! That is most certainly not the case here. I am a student at this gathering, not the teacher. Well, I thought then, what can I give you that might possibly increase your knowledge, your productivity, your success in your endeavors? Tonight I will try to bring you two things: perspective and a mission. A mission for each of you to take away from here tonight, and pursue.

To understand my view of the perspective which may help you to appreciate this conference and what it aims to accomplish, please allow me to recant a brief history of how alternative fuels swept me up and move me yet today.

In 1982, I was working for Celanese - the world's largest methanol producer, located at that time in Dallas, Texas. I was in a new methanol for fuel group. The scene at that time was that we had suffered the 1973 and 1979 Arab oil shocks. There were:

- long gasoline lines
- declining U.S. oil production
- economic woes
- an unstable world political scene
- growing concern over urban air quality
- a growing trade deficit
- farm foreclosures
- dwindling jobs in the oil patch

And a fledgling alternative fuels effort had sprung up.

There were neat methanol cars and buses in California. Ethanol in Brazil was just taking off. Propane, CNG and low percentage oxygenate blends were in use in the U.S. Ethanol blends were seen by some as a transition to neat fuels, but realistically at this time, they replaced lost octane from mandated lead phasedown (ironically to protect catalytic converters, not lead in environment, the last source in the US being AV gas.)

I began to attend conferences such as this one to learn about the issues. I gave testimony at a Congressional hearing at the Beech/Wichita activity center in Kansas which lead to support for the programs of NAA, Max Shauck and Gordon Cooper, and Bill Paynter. We knew something then that seems to have been forgotten now...that all alternative fuels needed to cooperate. We made methanol/ethanol blends for Max Shauck, for example. Today, the battle

between methanol and ethanol proponents must now delight some fossil fuel advocates for it overshadows the efforts that should be in the forefront .

But I digress...

I and my colleagues became embroiled in the politics of alternative fuels, absolutely necessary because it is a political issue, as well as their technical merit. Through these periods, I became a fuel scientist, serving on advisory panels with CEC, SERI, UMTA, & SAE and even a White House working group. I moved into the ethanol arena and devoted a considerable chunk of my life to developing ETBE as a fuel and commodity. Six years after we briefed President George Bush in Lincoln, Nebraska in 1989, ETBE broke ranks into significant commercial manufacture and use. While its market share is yet small, much is expected of this valuable ether, which I could go on about for hours (note: Max Shauck flew on ETBE at the Paris air show; plus it has good diesel solubility, therefore would work with blends for turbine applications). I directed research and development on advanced ether composition, was a pure marketer of oxygenates, ran a growing ethanol company, and now market for Delta-T Corp., the emerging leader on fermentation ethanol production technology.

Yet, nothing seems to have changed for me, in one sense, this whole time. And that is my perspective of the value of alternative fuels which only solidifies as new knowledge is revealed almost weekly. Here are the constants where alternative fuels can help.

For the economy:

- Domestic jobs (industry)
- Trade deficits (oil > 50%)
- Rural revitalization
- Protect American family farm
- Economic growth
- Industrial diversification
- Stable fuel supplies for commerce and the military

For national security:

- Must not have interruption
- We are at OPEC's mercy, never mind low prices now
- People have died in Kuwait, not Iowa
- Fossil fuels will run short - do we let our children solve this problem?
What will we say when they ask why we did this to them?

For the environment:

- Urban air filled with toxins, CO, benzene, ground-level ozone - respiration and health problems, billions in health care and lost productivity

- Now greenhouse problem is on us, caused by burning non-renewable fuels. What will we say when the ice caps start to melt and the Mississippi delta disappears?

These points are not aviation fuel specific, but your strategies must be developed in view of the larger context of all transportation fuels, and especially liquid transportation fuels. Being a smaller segment than over-the-road gas and diesel, you must adopt a strategy and set of tactics that move all areas forward, that are realistic and achievable with an acceptable price tag for the benefits that will follow.

Now for your homework, the mission I promised. To lay the groundwork, you must go out and communicate, teach what you know. Do not speak just to each other, but to all the people. Get creative. Find ways for all citizens to understand the importance, the necessity of your endeavors - build a grass roots, heartfelt base of strength that cannot be swayed by expensive ad campaigns by interests hoping to maintain the status quo until we are faced with economic, security, and environmental disasters. With the public firmly behind you, then complete your mission by finalizing a strategy for accomplishing these goals, a blueprint complete with tactics, milestones, and a clear, quantified picture of what it will cost and what it will achieve. If you do not know where you are going, I am certain you will never get there. Do what has never been accomplished and give us a cohesive field in which to operate. Stop the suicidal internecine wars between rival groups grappling for a sliver of a small piece of pie and reach together for the entire bakery. If you do any less, then look to yourself to see if you are truly committed to this course, this cause, and what it means.

George Bush wondered aloud in 1989 at the close of the ETBE briefing if there was then going to be a test on what I had just relayed. You administer your own test to yourself in six months -- a year -- five years -- 20 years from now. What will your report card look like?

I cannot step down without commenting on the patriotism, bravery and sacrifice of so many in this room, but especially Max Shauck, our host representing Baylor University at this event. I know I am only one of many in this room who has been scared witless by Max, both in the air with him and on the ground waiting for him. But I have also been proud to the point of tears at his accomplishments and selflessness and what it means to an audience when he puts his life on the line for alternative fuels. He has also shown uncommon good sense by choosing a life partner skilled in many fields, especially aviation, and Grazia deserves much credit for the success this team has given us. Enough. Thank you for your time and attention this evening and best wishes to you all.

KEY NOTE AND GENERAL OVERVIEW

PAUL B. MACCREADY
AERO VIRONMENT, INC.

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

International Conference on Alternative Aviation Fuels
Waco, Texas, November 2, 1995
Keynote and General Overview
Paul B. MacCready
AeroVironment, Inc.

Summary

The growing U.S. priorities on decreasing dependence on foreign oil, and on decreasing local and global pollutant emissions, have stimulated investigation of alternative fuels for powering air and land vehicles. There are many candidate fuels, each having positive and negative features when compared to existing fuels. Present distribution, markets, uses, and the advanced technologies of motors and vehicles are well tailored to these existing fuels. Before exploring features of alternative fuels and strategies for their possible uses, attention is given to the goals we want to achieve. Both land vehicles and aircraft are treated because they have much in common, and because the large, ongoing work on alternative fuels for surface vehicles provides a tremendous head start for aircraft projects. The alternative liquid fuel ethanol, from renewable U.S. biomass, shows special promise for some ground and air vehicles. Compressed natural gas, a large resource, best fits buses, medium/large trucks, and small vehicles in fleets, all able to handle problems associated with extra weight, fueling, and limited distribution. The low net energy per unit weight and volume (including storage systems) makes it unsuitable for most aircraft. The negative aspect of hydrogen, namely the volume problem and the weight of storage systems, probably overwhelm its considerable positives. The use of alternative fuels in aircraft will generally decrease performance and put some emphasis on improving the efficiency of the airplane and its use. Alternative fuels may offer more societal value for cars, because overall so much more fuel is used for land vehicles than aircraft, and the demands on cost and weight are less strict in the case of cars.

Introduction and Background

The dependence of the U.S. on fossil fuels stems from the fact that these fuels are wonderful in their role of powering vehicles: convenient, efficient, inexpensive, available at many locations, and representing the fuels for which there exists a tremendous background of technology and practical experience. To a considerable extent, the U.S., and our habits and expectations, are designed by our wide use of fossil fuel.

Unfortunately, there are negatives. These fossil fuel resources are large but finite, and thus limited. The resources increase when higher future prices make the production from more expensive sources economically feasible, but there are obvious challenges that will arise in the future from harnessing the growth of our industrial wagon to a single horse

that will eventually starve. Over half our consumption now comes from imported supplies, causing some \$60 billion of our balance of payments problems, and causing the U.S. to get increasingly fuel-dependent on other countries that may not be philosophically, politically, or militarily compatible with us.

Thus, logically and inevitably, the search for substitute fuels gains strength. However, in the U.S. this search represents somewhat of a swim upstream because by not considering these negatives in the price of existing fossil fuels, there is an inherent subsidy for these fossil fuels, a subsidy unavailable to alternative fuels. We the voters will not permit the price of gasoline to represent its real cost. Even with the present taxes, in California gasoline is the least costly liquid after tap water. We voters do permit government to aid the introduction of some alternative fuels (and battery energy) by subsidies and regulating some market demand (especially through fleets).

In our look at future alternatives for powering vehicles attention needs to be given to fossil fuels available in the U.S. (oil, gas, shale oil, coal). More attention deserves to be put on renewable fuels, or energy, that are generated here. Whatever the fuel, pollutant emissions that may adversely affect global and local environments and human health should be considered in the context of both the entire fuel production/distribution system and the end point fuel-to-mechanical energy conversion process.

Obviously there are many factors of availability and suitability to consider, and there will be many different solutions to different needs. This brief presentation cannot cover the details, but can try to set the stage for others. Inevitably, there will be conclusions that include:

- Decreasing transportation energy use through improved vehicle efficiency, by intermodal transportation systems; and even by moderating transportation demand.
- The switch to alternatives creates stresses, but this can be treated as opportunity. Civilization must have alternative fuels.
- The solutions employed in 25 years are likely to be beyond our present imaginings.

Goals -- The Auto Example

The usual car goal mentioned is: if existing fuels create problems, find an alternative without these problems. Thus the lead was removed from gasoline for autos. But pollution and energy resource limitations remain for cars, and so alternative fuels and battery power are being investigated. Manufacturers working the battery option quickly realized that battery energy storage was (and will probably always be) so limited in comparison with chemical combustion that mechanical efficiency of the vehicle needed improvement. That wasn't enough, so recharging infrastructure was pushed, but since that still wasn't enough the focus moved to finding the limited niches where short range but clean battery-powered cars would make market sense. And it was realized that even inexpensive, zero energy, zero pollutant cars would not decrease traffic or parking stresses or time lost commuting. All these realizations stimulated studies on

transportation systems: seamless intermodal travel, land use planning, congestion management, life styles, home vs. office relationships, and decreasing travel by 4-day work weeks, telecommuting, parking and highway use fees, etc. The real, underlying goal for individual transportation turned out to be sustainable accessibility, not merely an alternative fuel as desirable for the individual user as gasoline. There are many ways to achieve the goal of improved accessibility, and therefore many strategies to activate. Alternative fuels is just one reasonable strategy.

Goals -- The Airplane Cases

Airplanes, or trucks, trains, or ships, are far different than cars, but each justifies the same careful look at goals. Modern technology is rather good at achieving goals. Let's make sure the goals we set are the ones we, in the future, will really want.

Reciprocating engine aircraft (small private, and small carriers) flown for business and recreation scarcely compete with cars in numbers and traffic. And because fuel efficiency plays a high priority role in the practical use of aircraft, most such aircraft are already relatively efficient. The potential for improvement is less than for cars. Of the total U.S. transportation energy consumed in 1992, cars and light trucks were 46%, trucks 37%, air carriers 10-11%, water carriers 6%, and rail 2%. If we estimate the aircraft reciprocating engine energy at 1% of air carrier fuel, it turns out to be only 0.1% of total transportation energy. If the fuel use in reciprocating engine aircraft were to drop to zero, the difference would be "de minimis," below any significant figure comprising total transportation energy. The estimate that reciprocating engine energy consumption is 1% of air carriers is a guess, but the inaccuracy is unlikely to alter the conclusion that switching from gasoline to an alternative fuel makes little sense from a countrywide energy or global pollution perspective. It may be marginally useful from the standpoint of local pollutant emissions, but I suspect that few airports that serve such aircraft are located where the surface and low altitude operations of such planes would have a significant effect on air quality. The big value of switching to alternatives may be in providing a dramatic example of responsible change, and improving technology that has wider application elsewhere. In any case, there is a strong incentive to provide an alternative fuel that maintains, without lead, the high octane of aircraft gasoline.

The turbine jet, turbofan, and turboprop planes that comprise the carrier fleet and consume 10-11% of the total transportation energy burn kerosene (jet fuel) in enough quantity to contribute some significant local and global pollution and consume significant non-renewable, imported fuel. A goal of eventually using alternative fuels for air carriers is reasonable. However, in practice the alternative fuels may, for one reason or another prove inconvenient substitutes for jet fuel.

The highest value use of fossil fuel will be a use for which substitutes are very inconvenient, expensive, have other severe negatives, or are simply not practical. Probably the highest value use is as feedstock for petrochemicals. Next on the value list is its use for commercial airlines for which practical, economic substitutes may not prove feasible. Then in order I would list reciprocating engine aircraft, trucks, cars, boats, power generation, and heating. The lower on the list, the easier the task of finding satisfactory substitutes. If the overarching goal is transport of persons and goods rapidly

and economically by air by means sustainable in the long run, alternative fuels deserve priority as a strategy. In the shorter run, such fuels serve society better applied to major fuel consumers for which the substitutes are more feasible.

Perspectives From Nature

Natural flight evolved in at least four forms: bugs, birds, bats, and pterosaurs. Birds, and some insects, make long journeys, consuming nearly 50% of their weight burning their fuel, fat, to generate physical power at about the same efficiency as reciprocating engines. There are usually a number of satisfactory alternatives for the food to eat to create the fat. Long distance aircraft may consume comparable percentages of fuel. Some natural creatures are helped during migration and foraging by utilizing free energy (primarily upcurrents) from the atmosphere -- energy unavailable for routine use by normal aircraft.

The high power required for natural flight is more than that needed for surface travel. Air must be accelerated down to provide a compensating lift force, and accelerated back to provide thrust to overcome air resistance, while the surface creature, or vehicle, gets the lift and thrust more efficiently by connecting to solid ground rather than fluid air. Thus it takes a more complex and powerful creature to fly, but the virtues of flight are so great that many creatures evolved the capability because it helped with survival: moving easily over complex terrain, foraging over great distances, undertaking long migration to better locations, having a third dimension to escape predators and to find food. Humans, with engine-powered flight starting about a century ago, find somewhat similar benefits. The marketplace has served as a selection process whereby the evolution of amazing flight vehicles has proceeded a million times faster than nature's unstructured evolutionary procedure.

Cars vs Airplanes

Information derived from extensive studies of alternative fuels for cars is a good starting point for looking at alternative fuels for aircraft. Thus a "broad-brush" comparison of fuel use in cars versus reciprocating engine aircraft is appropriate here.

Figure 1 outlines where fuel energy goes in representative small land and air vehicles. Eventually it all goes into heat, but along the way some of the mechanical energy delivered by the engine is put to the desired purposes of propelling the vehicle and powering accessories used for communications, instruments, lighting, servos, and passenger comfort.

For a hybrid land vehicle (battery electric drive, with on-board recharging from a chemical fuel device) and the airplane, most of the time the engine is operating not far from the realm of maximum fuel efficiency. Consequently, about 30% of the fuel energy is converted to mechanical power, 70% being wasted in the engine. Fuel consumption can be about 0.4 lbs/horsepower hour. For an ordinary car, the engine is mostly operating at a power only some 10% of peak power, far from an efficient operating point, and sometimes the engine is idling -- essentially zero efficiency. Thus an average mechanical yield of only 18% or less instead of 30% can be anticipated. The hybrid car of the future

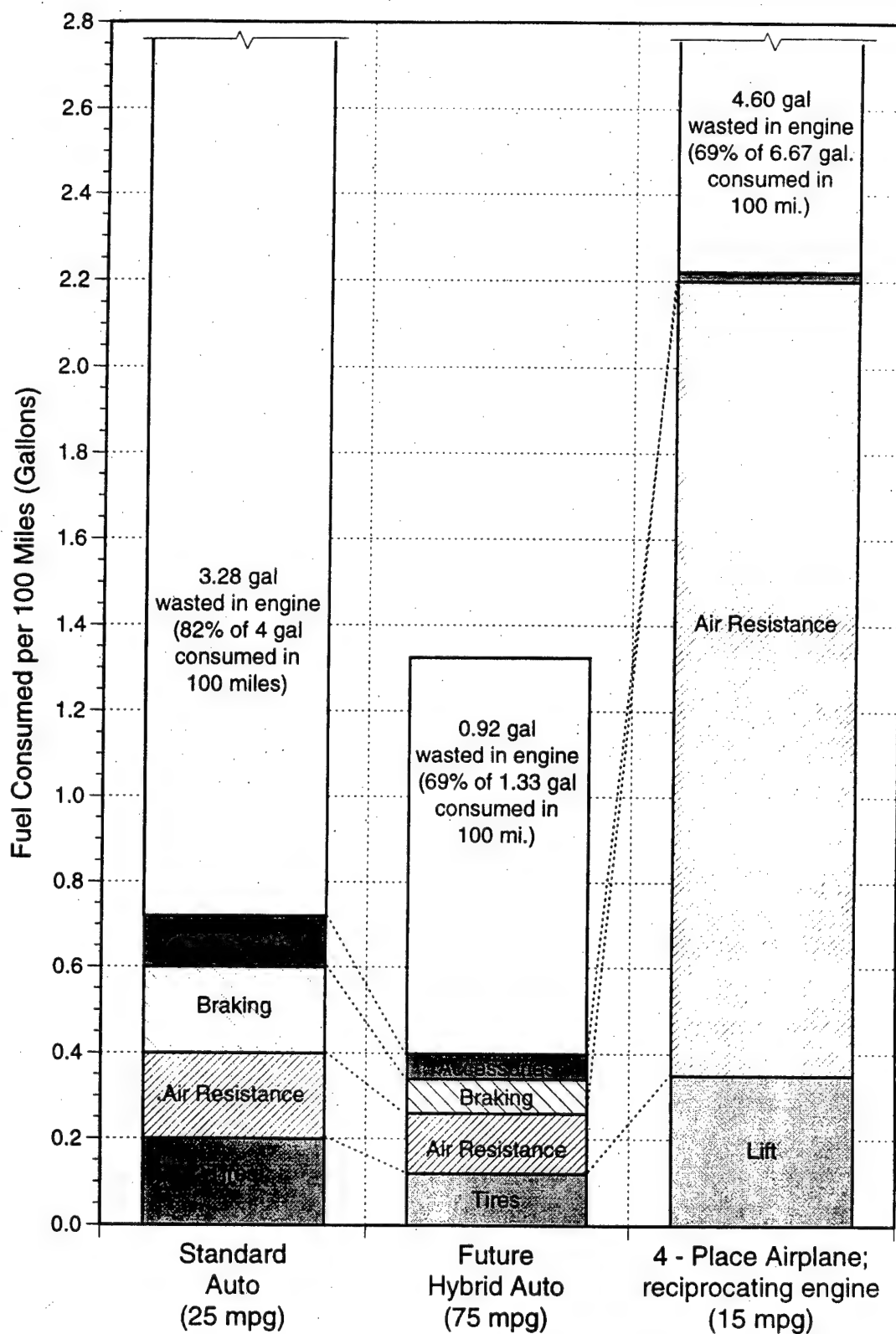


Fig. 1 Use of fuel per 100 miles for representative vehicles, (autos for combined urban / highway cycle; airplane for mostly distance flying).

derives its propulsion energy more efficiently, and also will use this propulsion energy more efficiently. Lower weight, tires with lower drag coefficient, better aerodynamics, recovering some braking energy by using regeneration, decreasing accessory load and improving accessory efficiency -- all combine to improve fuel efficiency threefold.

The 4-passenger airplane virtually eliminates braking losses and accessory loads. It replaces tire drag with aerodynamic induced drag, the drag associated with generating lift. Aerodynamics produces lift more inefficiently than do tires, but when an airplane cruises at speeds much above the speed for best glide angle the induced drag becomes much less than parasite or profile drag associated with the air resistance to forward motion. The airplane, without roads and close traffic, is permitted to move much faster than the normal car, and needs big wings not required by cars, and so this air resistance is the dominant energy consumer. It cuts fuel efficiency. If the plane cruised at a high altitude where air density lowers the air resistance much more than the lift drag increases, it would get better fuel efficiency (and greater speed).

For comparison, if a large, extremely efficient 2-passenger powered sailplane were flown at 100 mph, 100 mpg would be achievable with an engine delivering 13 horsepower.

The conclusion is: for aircraft fuel considerations, learn from cars but be aware of the differences between energy use in cars and airplanes.

Fuels

Continuing the broad perspective, Fig. 2 shows a number of energy sources for life and technology on earth, and makes the point that virtually everything is solar powered if we consider the appropriate time constant. For fossil fuel the time is millions of years -- renewable only if you are extremely patient.

The following list presents the main fuels used, or having a potential for use, in transportation.

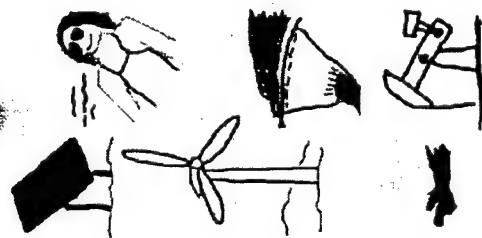
Present fuels widely used in U.S.

| | |
|---|-----------------------------------|
| Gasoline -- cars, airplanes with reciprocating engines, and chemical feedstocks | 58% of U.S. transportation energy |
| Kerosene -- airliners, tractors Diesel (gas oil) -- diesel trucks | } 28% |
| Fuel oil -- ships, power plants | 14% |

These are derived by selective processing of oil from various sources. The U.S. consumes one quarter of the world's oil production. The transportation sector represents approximately two thirds of this U.S. oil consumption. Emissions from 190 million cars

SOLAR ENERGY SUPPLY

*All the energy used on earth comes from sunlight. **



| | | NOW |
|---|--|----------------------------|
| • Photovoltaic Solar Cells | Turning sunlight into electrical energy at this moment. | |
| • Solar Thermal Heating | Warming us, our water, our homes, and our environment at present or over the last few hours. | HOURS |
| • Wind Power | Using the wind associated with recent weather powered by the sun a few hours, days or weeks ago. | DAYS |
| • Hydro Power | Using the flow of rivers that were replenished by rain that resulted from heating the continents and oceans over the recent weeks or months. | WEEKS |
| • Burning Wood | Using the stored energy of sunlight that supported the life of the tree over the last 10 - 100 years. | MONTHS |
| • Burning Fossil Fuel (Oil, gasoline, natural gas, coal) | Using the stored energy of sunlight that powered the growth of plants and animals millions of years ago. | YEARS MILLIONS OF YEARS |

All these energies are renewable, but on a human time scale we find it inconvenient to wait millions of years for fossil fuels to be regenerated. Hydro, wind, and solar are truly renewable on our human time scale. Burning wood (and other biomass) is renewable energy on our time scale - but only if we don't consume it too fast and run out.

* Except for the small portion of nuclear, geothermal and tidal energy.

Fig. 2 Solar Energy Supply

and trucks account for about half of all U.S. air pollution and more than 80% of urban air pollution.

The octane (anti-knock) capability of gasoline is improved by lead, but lead is now virtually phased out for surface vehicles and octane levels are maintained by oxygenators such as MTBE (methyl tertiary butyl ether). Higher octane permits engine tailoring (especially compression ratio) for more power and efficiency; useful for cars, more important for aircraft.

Some Alternative Fuels

- Methanol (neat; pure; M-100; CH_3OH)
- Methanol blend (M-85; 15% gasoline)
- CNG (Compressed Natural Gas, mostly methane, CH_4)
- LPG (Liquified Petroleum Gas)
- LNG (Liquified Natural Gas)
- Ethanol (denatured)
- Reformulated gasoline (oxygenated with 15% MTBE)
- Clean diesel
- Hydrogen
- Electricity (battery as energy storage)

The 1990 Clean Air Act requires individual states to implement clean-fuel fleet programs. The 1992 Energy Policy Act requires the Department of Energy to implement an alternative-fuel fleet program.

There are many details to consider about each of the alternatives in the above list: sources, storage, energy density by mass and volume, suitable devices for converting to mechanical energy, pollutant emissions, costs, etc. This brief presentation cannot cover such details, except that in subsequent sections a few of these alternative fuels offering especially attractive features are examined.

The Special Case of Ethanol

Ethanol, mostly from corn, is now used for some U.S. transportation as a blended fuel (10% ethanol, 90% gasoline). This oxygenated blend helps decrease pollutant emissions. In Brazil, to avoid dependence on foreign oil, ethanol from sugar is the primary surface transportation fuel -- but its high cost is causing rethinking of the program. Brazil uses hydrous ethanol, and by operating with high compression ratio engines achieves only an 11% decrease in mpg compared to gasoline.

Research on ethanol derived from plant fibers is very encouraging. The National Renewable Energy Lab at Golden, Colorado is the focal point. By 2005 this ethanol may have the following features:

- Availability. The source material is biomass. The preferred process utilizes energy crops such as trees (fast growing hybrid poplars) or switchgrass, grown on land not presently used for conventional agricultural products (providing new jobs/income for farmers).
- Cost. 65 cents/gallon is a not unreasonable target.
- Environmentally attractive. Following the whole biomass-to-ethanol cycle shows 4.1 BTUs of ethanol fuel energy can be derived for every 1 BTU of fossil energy consumed in the growing and processing. In comparison, the production of reformulated gasoline generates only 0.8 BTUs of fuel energy for every 1 BTU of fossil energy consumed in the production process. In comparison with reformulated gasoline production and use, the net carbon dioxide produced by the ethanol process is 90% lower, and the sulfur dioxide emissions 70% less. If ethanol is consumed in the growing and processing, ethanol's environmental attractiveness is even greater.

Ethanol, at 85,000 BTU/gallon, only offers an energy density 68% of gasoline at 125,000 BTU/gallon. Experience with ethanol for small airplanes at Baylor University has demonstrated that engines converted to ethanol use can be certificated by the FAA; detonation at high compression is reduced and the plane achieves more power and lessened pollution; in spite of a 32% lower energy content than gasoline, because of high thermal efficiency the range decreases only 10-20%; the fuel has low vapor pressure and so creates less vapor lock problems.

A key feature of ethanol is its high octane rating, obtained without lead. Where high octane is essential, as for high power and efficient aircraft engines, and lead additives are getting prohibited by regulations, the ethanol star rises higher.

The importance of octane ratings for aviation was stressed by famous pilot Dr. Jimmy Doolittle in the 1930s. In 1931 Shell, for which Doolittle consulted, made the commitment to build a plant producing high octane fuel. Airlines were using 91 octane fuel (15 cents/gallon) as standard, adding tetraethyl lead for takeoff. By 1938 leaded 100 octane was standard for the military (except 91 octane still for trainers). 1934 tests on a Boeing P-36 pursuit plane had shown a 25% power increase from going to 100 octane from 91. 100 octane fuel powered virtually all military aircraft of the major participants in WWII. 100 low lead at present powers most reciprocating engine aircraft. 80/87 still is used for old aircraft with low compression engines.

Hydrogen

Hydrogen gas is a desirable fuel because it can be generated from various fossil fuels and also from electrolysis of water (and hence store and transport the electric energy from windmills, solar farms, and hydro and nuclear power plants), and it burns clean. It can drive a reciprocating engine, but it can also be the fuel for conversion to electricity via a fuel cell. The practical fuel cell has moderate (about 40%) efficiency. The big problem is that hydrogen storage for mobile uses requires heavy pressure tanks or cryogenic storage in insulated tanks for liquids, or absorption into a heavy hydride material. The storage system may weigh 25-40 times more than the hydrogen it sequesters. The BTU per pound is excellent, 51,500 BTU/lb, vs 19,000 BTU/lb for conventional gasoline, but the volume and/or weight of a storage system carrying it is large -- too large for practical

use in an airplane. One can operate a special car or airplane on hydrogen, but there are more useful alternatives.

CNG

After coal, natural gas is the most abundant fossil fuel, with twice as much proven supply as petroleum. It saves on CO₂ emissions because of the small ratio of carbon to hydrogen in CNG. Stored in a 3600 psi composite tank, a 15 lb tank and gas has the energy of a 7.8 lb gallon of gasoline plus associated tankage. In other words, for the same range the vehicle must carry twice the weight of a gasoline system (and at a considerably larger volume). This means CNG becomes suitable as a fuel for cars and light trucks as the vehicles are made more efficient so that they require less energy per mile. CNG is relatively widely available. For airplanes, wherein fuel weight is so critical to long range performance, CNG is not a viable alternative fuel for normal use.

Methanol

Methanol is produced from natural gas, coal, or biomass. M85 (85% methanol, 15% gasoline) is used for spark ignition cars, M100 for compression-ignition engines. Its low energy content compared to gasoline cuts car range substantially.

Methanol's special attraction, aside from local U.S. production (more than 90% used in the U.S. is produced in the U.S.), is its suitability as a convenient liquid fuel for fuel cells for electric cars. With an on-board reformer it can produce the hydrogen gas that powers the fuel cells, and developmental programs are underway to eliminate the reformer, in effect to incorporate it into the fuel cell process. Some pollution is produced that would not occur compared to hydrogen gas, but the total energy storage on a vehicle can be much higher than with hydrogen. Starting with 100% chemical energy in the methanol, 65-70% remains in the hydrogen after the reformer, and then, through a 45% efficient hydrogen fuel cell, the electric energy content is near 30%, meaning about 27% mechanical energy may be obtained from an electric motor shaft. If the methanol fueled a standard reciprocating engine, approximately the same overall efficiency for powering the mechanical shaft is obtainable. Going the experimental fuel cell route does offer the advantage that the efficiency can remain high even at low powers, which is not the case for the reciprocating engine as normally used. Another advantage of going the electric route is that a buffer battery permits car efficiency improvement through regenerative braking (not of value for aircraft use).

The reformer-fuel cell technology is not yet well advanced, and its eventual economics are unclear, while reciprocating energy technology is in good shape, proven and inexpensive. Methanol is a good example of the mixture of pluses and minuses inherent in exploring the viability of alternative fuels. Like ethanol and gasoline, methanol is a liquid fuel that stores high energy, can be distributed conveniently, and readily fuels car tanks.

Final Comments

It is instructive to try to examine the assessment you will be making in 2015 about the commitments made and actions taken in the mid 90s to deal with the energy challenge. The challenge arises from the fact that civilization's rapidly increasing energy demands put stresses on an earth whose resources are limited. The challenge is how to meet civilization's growing demands and needs for the conveniences that are based on energy, while finding some reasonable balance between nature and technology, and along the way fitting into the realities of economics and politics amid a public whose interests tend toward emphasizing the present and short term over the future.

In the energy area there are so many technological and system and policy approaches available now, with more visible on the horizon, and certainly some great ones beyond the present view of anyone, that I am convinced we have the tools for the job. The stakes are high. Inaction is unacceptable. There are intellectual, economic, and technological forces to unleash, and jobs and profits awaiting. There is no perfect project or single solution. Instead, in this period of change and uncertainty, many avenues deserve exploration. If all succeed, we obviously were not stretching ourselves as much as we could or should.

Your 2015 assessment will likely show that in the mid 90s we did well exploring alternative energies, vehicle efficiency, and transportation systems, but not as well as the real priority justified. Also you will note that it took some jolt to get priorities sorted out, and that the attitude-changing jolt occurred before 2005 from some giant negative economic, political, or military consequence of the increasing U.S. dependence on foreign oil.

Reference Materials

This overview paper does not give specific references. As general background I suggest:

Taking an Alternative Route. Occasional publication produced by Dept. of Energy. Contact National Alternative Fuels Hotline, 800-423-1DOE.

Ethanol. Various publications by M. E. Shauck and his associates. For information contact Renewable Aviation Fuel Development Center, Dept. of Aviation Sciences, Baylor University, Box 97440, Waco, TX 76798.

Fuel Cycle Evaluation of Biomass - Ethanol and Reformulated Gasoline; Overview. Information Center, National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, Colorado 80301-3393. Ph: 303-275-4347.

Transportation Energy and Environment: Balancing Goals and Identifying Policies. 1995. Consumer Energy Council of America Research Foundation (Transportation, Energy, and Environment Project). 2000 L Street NW, Suite 802, Washington, D.C. 20036.

Automotive Fuels Reference Book, Second Edition. 1995. Keith Owen and Trevor Coley. Published by Society of Automotive Engineers Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001. Ph: 412-776-4841; Fax: 412-776-5760.

WORKSHOP ON CERTIFICATION PROCEDURES

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FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Workshop on Certification Procedures

The First International Conference on Alternative Aviation Fuels

■ **Fuel Properties**

– **Octane**

» **Not all Octane Ratings are Alike**

- Motor/Aviation Lean
- Research
- Aviation Rich
- AKI or Performance Index or Road Octane Number

» **Pre-ignition**

- Methanol Worst

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2

I must emphasize that not all octanes are the same. You must be careful when reading octane claims by the different suppliers. Most will quote the Research Number which has no meaning in aviation.

The Motor rating is related to the Aviation Lean rating and this system is designed to measure the fuels response to heavy duty cycles.

The Research Number is for light duty cycles.

The Aviation Rich rating is for severe duty cycles in highly turbocharged or supercharged engines.

The AKI is the average of the Motor and Research Numbers. It is also called the Performance Index or Road Octane Number.

Pre-ignition can be more severe than detonation. During testing, CHTs ran from 500 to 750+ in less than 30 seconds.

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■ **Fuel Properties (cont.)**

- Reid Vapor Pressure
 - » **Gasolines with Alcohols Have Unusual Behavior**
 - » Vapor to Liquid Ratio Test Better Indicator
- Flash Point
- Flammability Limits
- Stoichiometric Air to Fuel Ratio
- Freeze Point

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3

The RVP is a test designed specifically to measure the volatility of gasolines. A better measure of volatility is the V/L Ratio test. Gasolines that contain alcohols behave as though they have significantly higher RVPs than the test indicates. Gasolines with 3% methanol/TBA tested to 12.5 psi but behaved like 19 psi fuels. Fuels that are primarily one component tend to vapor lock at their boiling point.

The Flash Point is a critical safety test. If the temperature of the fuel is near the flash point, explosive mixtures will occur in the tank. Adding small amounts of gasoline suppress the flash point. This is a common practice with alcohols.

The flammability limits describe the air to fuel ration where combustion can occur. If there is not enough fuel, the mixture won't burn. Likewise, if there is too much fuel it displaces the air and the mixture will not burn.

The Stoichiometric air to fuel ratio is when there is enough fuel to consume all the oxygen in the air. Gasoline 12.8 to 13.5, ETBE 12.2

Freeze point is a concern for high altitude operations.

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■ **Fuel Properties (cont.)**

- Specific Gravity
- Color
 - » Changes for tax Laws
- Heat of Combustion
- Latent Heat of Vaporization
- Distillation
 - » Initial Boiling Point

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4

The fuels that contain oxygen (alcohols & ethers) tend to have higher specific gravities. This is a consideration for payload.

Colors: Changed by law for tax purposes:

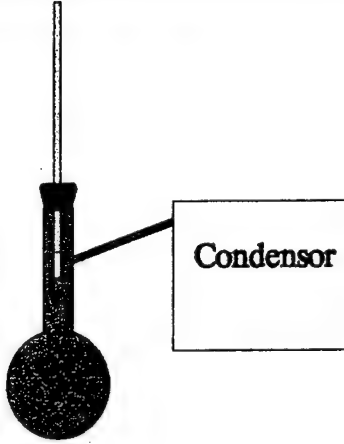
100LL is Blue, 100/130 is green, 80/87 is red, Regular Unleaded is red/orange, and turbine is straw colored. Low Sulfur Kerosene is dark red. Premium autogas should be clear or straw colored.

The Heat of Combustion is a measure of the energy density of the fuel. The lower heat of combustion takes into account the energy required to vaporize the fuel (i.e., net heat of combustion).

The Latent Heat of Vaporization is the heat required to vaporize the fuel. If the heat of vaporization is high enough, it will affect the power output by increasing change efficiency.

The Distillation is a rough measure of the components found in the fuel. The initial boiling point (IBP) is the temperature where the distillation test starts to see fuel condensing. It is not the temperature of the liquid in the test. See next slide.

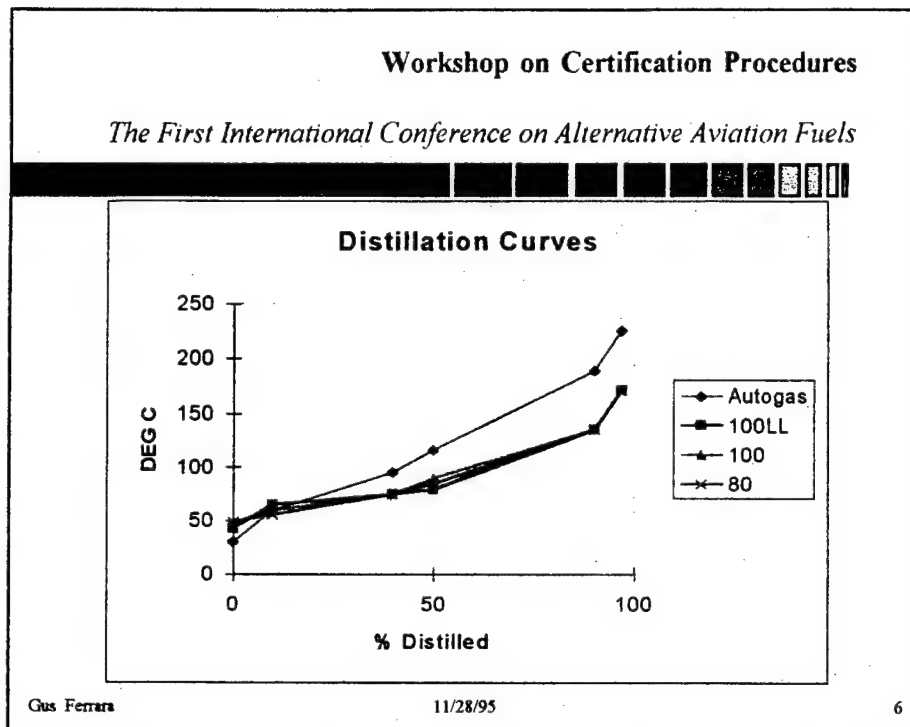
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The distillation test measures the temperature of the vapors above the liquid. The temperature of the liquid is approximately 25 °F higher than the temperature of the vapors above the liquid.

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The thermometer is placed where the gasses exit the flask for the condenser. The initial boiling point is read when the first drop falls from the condenser. The temperature of the liquid is typically 25 degrees Fahrenheit hotter than the initial boiling point. Ideally, the temperature of the liquid at the IBP is the temperature where the hot fuel certification will be conducted. For example, an autogas will have an IBP of 85 degrees Fahrenheit but the liquid will be about 108 degrees Fahrenheit.



The above show some typical distillation curves. The 100LL is flat because of the presence of toluene.

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■ **Other Considerations**

- Phase Separation
 - » Can Have Separation at Altitude as Fuel Cools
- Oxygen Atom Does Not Improve Altitude Performance
- Denaturing
 - » Flash Point & Legal Considerations
- Alcohols & Ethers Scavenge Lead Deposits

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7

Phase separation occurs when the fuel cools below the point where the alcohol/water concentration is too high to be dissolved. Since aircraft tanks are vented, water will be picked up continuously. Most likely, this will be a problem as the aircraft climbs into cooler air and the fuel cools. If phase separation occurs, the remaining fuel will likely have a lower octane rating than called for in the specification, especially with autogas blends.

Note, higher alcohol concentrations do not mean more water can be dissolved.

The presence of the oxygen atom in the molecule does not improve altitude performance. There is no mystical energy or efficiency gain at altitude.

The alcohols must be denatured for safety reasons. Flash Point and flame luminosity are the principal reasons. Ethanol must also be denatured for legal reasons. Typically 3 to 5% gasoline will be adequate for denaturing.

The alcohols and ethers seem to scavenge the lead deposits out of the engine. The first oil change after switching a used engine to these fuels must be made sooner than normal to compensate for this behavior.

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■ **Other Considerations (cont.)**

– **Concentration Calculations**

Calculate the weight of denatured ethanol (A)
to be used to obtain the desired concentration:

p = the desired concentration of alcohol

g = weight of gasoline used as a base

d = percent of gasoline in denatured ethanol

$$A = (p * g) / ((1 - d) - p)$$

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8

When performing concentration calculations, you must take into consideration the presence of denaturing agents and the fact that the concentration is typically listed as a function of the weight of the gasoline and the blending agent. If the blending agent is not denatured, then d is zero.

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■ **Other Considerations (cont.)**

– **Concentration Calculations (example)**

$p = 0.05$ (5% will be the final concentration)

$g = 280 \text{ \#}$

$d = 0.03$ (the alcohol is denatured with 3% gasoline)

$$A = (.05 * 280) / ((1 - 0.03) - 0.05) = 15.21 \#$$

$$\text{Final Conc.} = (0.97 * 15.21) / (280 + 15.21) * 100 = 5\%$$

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■ **Material Compatibility**

– Autogas/Methanol is Typically the Worst Case

» **Elastomers**

- Swell
- Tensile Strength
- Porosity

» **Metals**

- Corrosion
- Reactivity (for gums)

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10

Material compatibility is a problem that is more economic than safety, though if material problems are ignored long enough, they will kill you.

Typically problems with elastomers are swell, reduction in tensile strength and porosity. Some materials will experience crazing (cracking) if the problem is severe enough. My experience indicates that the materials that can handle 100LL will give reasonable performance for all fuels except methanol blends.

Metal corrosion can be severe, especially with the gasoline methanol blends. Never use magnesium with methanol. It will dissolve. There are corrosion inhibitors that suppress this problem, but they increase the cost of the fuel.

Some metals such as copper act as catalysts and they speed the formation of gums that will harm the system over time.

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■ **Practical Considerations, Hot Fuel Test**

- Store & Transfer Gasolines below 50 °F
- Adjust RVP In-house
- Heat Fuel in Situ
 - » Composite Aircraft may be a problem
 - » Heating Time Must be Less Than 3 Hours
- Engine Should be at Operating Temperature Before Takeoff

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11

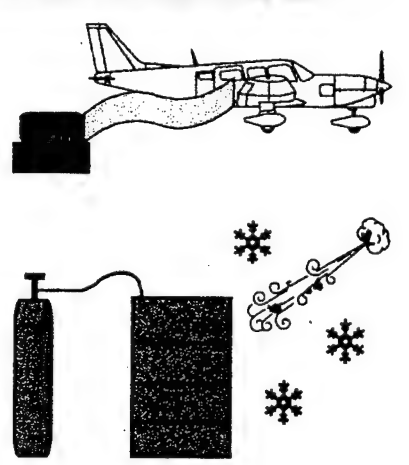
When conducting hot fuel certification tests:

1. Store the test fuel in sealed containers below 50 degrees Fahrenheit.
2. Heat the fuel after it is placed in the aircraft. See next slide for method that I used.
3. Preheat the engine and bring it up to operating temperature before initiating flight.
4. Do not allow the fuel to sit at high temperatures for more than three hours.

If the test fuel is slightly lower in RVP than required for the test, the RVP can be increased. See the next slide.

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- Blower and duct proved effective for heating fuel in-situ.
- Preheat engine to speed warm-up.
- Bubble propane or butane through chilled gasoline will raise RVP.



Gus Ferrara 11/28/95 12

I used a space heater that put out about 250 degree Fahrenheit air. I placed this heater about 1 foot from the entrance to the duct, which allowed it to mix with ambient air. By moving the duct relative to the heater, I was able to adjust the outlet temperature. This is an important consideration of or composite aircraft. For example, the some aircraft cannot be operated when the airframe is above a certain temperature.

To increase the RVP, chill the fuel to about 40 degrees Fahrenheit and slowly bubble propane or butane into the fuel. If it done slow enough, the bubbles will vanish before breaking the surface. Retest the fuel to see if the RVP is high enough. The change is linear with weight. A small propane tank is enough to raise the RVP of a barrel of fuel about 1 psi. **USE APPROPRIATE EQUIPMENT AND VENTILATION!**

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■ **Fuel Specific Considerations:**

– **Autogas**

- » Do Not Heat Above 110 °F
- » High Aromatic Content
 - Material Compatibility with Elastomers
 - Soot Formation
- » Probably Contains Trace Amounts of Alcohol
 - Material Compatibility with Elastomers
 - Affects Vapor Lock Behavior
- » Contains Detergents

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13

Do not heat gasoline above 110 degrees Fahrenheit.

Autogas has a high aromatic content, which tends to increase soot formation. Soot deposits will result in a significant octane requirement increase. The aromatics also aggravate material compatibility problems.

Autogas will probably contain trace amounts of alcohol. This aggravates the material compatibility problem and affects volatility.

Autogas contains detergents that will form emulsions if accidentally mixed with bulk water. The detergents may also clean out old systems that operated on Avgas in the past. I suggest flushing tanks before switching.

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■ **Fuel Specific Considerations (cont.):**

– **Gasohols**

» **Unusual Volatility Considerations**

- Fuel Temperature, 95 to 100 °F
- About 12.5% Alcohol
- These are the Worst Case

» **Phase Separation**

- Concern as fuel chills at altitude
- Contamination with Bulk Water

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14

Gasohols have unusual volatility behaviors that are not predicted by the RVP. The test should be conducted with a fuel temperature from 95 to 100 degrees Fahrenheit and with an alcohol concentration of 12.5%. This is the worst case fuel for vapor lock. If it passes with this fuel, all others gasoline blends will pass.

Once again, phase separation is a concern with these fuels. Phase separation could occur as the fuel chills at altitude or from the addition of bulk water. Theoretically, phase separation could occur as a consequence of absorbing moisture from the air while the aircraft sits.

If phase separation occurs, the engine will not run on the phase that settles to the bottom, and the balance of the fuel will probably have a lower octane than specified for the fuel.

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■ **Fuel Specific Considerations (cont.):**

– Gasohols (cont.)

» Material Compatibility

- Metals Corrosion
- Methanol Blends Worse than Ethanol

– Alcohols

» Vapor Locks Near Boiling Point

» Some Recovery by Engine Redesign

» Some Material Compatibility Problems

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15

The methanol blends are worse for material compatibility problems. The only corrosion problems noted were for gasoline methanol blends in my testing.

Neet (straight) alcohols will vapor lock when the fuel reaches the boiling point. Care should be taken to ensure the fuel system will not approach the boiling point of the fuel.

Because of the high latent heat of vaporization, there is an increase in the charge efficiency (the amount of fuel and air going into the combustion chamber) and this will result in a slight increase in power. Other features of these fuels allow for recovery by increasing the compression ratio and operating at very lean air to fuel ratios.

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■ **Fuel Specific Considerations (cont.):**

- Alcohols (cont.)
 - » Bulk Water Contamination
- Methanol
 - » Pre-ignitions Problems near Stoichiometric
 - » Will Aggressively Attack Aluminum
- Ethanol
 - » Not as Aggressive as Methanol

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16

If the alcohol is denatured, bulk water contamination can result in the formation of an emulsion.

I experienced problems with pre-ignition on methanol, where the CHT went from 500 to 750 degrees Fahrenheit in less than 30 seconds. The only way to stop the pre-ignition was a reduction in power to idle. Don't worry about cracked cylinders, the engine will melt first if you go down slowly.


Pre-ignition can be avoided by operating lean of stoichiometric. If the engine is set up to operate lean of stoichiometric to avoid pre-ignition, the system should ensure the air to fuel ratio does not approach stoichiometric as the aircraft climbs. In racing methanol is mixed with water, this helps to suppress pre-ignition but it affects range.

In general, the material compatibility problems with ethanol are less severe than with methanol.

Ethanol is a renewable fuel.

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■ **Fuel Specific Considerations (cont.):**

- **Methyl-tertiary-butyl Ether (MTBE)**
 - » Vapor Locks Near Boiling point
 - » Material Compatibility Problems are not as Severe as Alcohols
 - » Can Be Blended without Phase Separation Concerns
 - » Relatively High Energy Density
 - » Unpleasant Smell/Possible Headache if 100%

Gus Ferrara

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17

Like alcohols, neat MTBE will vapor lock near the boiling point.

In general there are no material compatibility problems. Viton swells in MTBE and gasolines with MTBE.

MTBE can be blended with gasolines without phase separation or water problems.

MTBE has a relatively high energy density (83 % of Avgas).

MTBE has an unpleasant smell and can cause headaches when it is used as a neat fuel.

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■ **Ethyl-tertiary-butyl Ether (ETBE)**

- Vapor Locks Near Boiling Point
- Highest Energy Density of Candidates Discussed
- Highest Motor Octane
- Unpleasant Odor
- Partially Renewable

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18

ETBE behaves like MTBE. Vapor Lock will occur near the boiling point of the neat fuel, and it can be blended with gasolines without concern for phase separation and water solubility problems.

ETBE has the highest energy density of the alternate fuels discussed (85% of Avgas). The energy density is still low enough that the fuel system modifications may be required.

ETBE has a motor octane number of 102. This is the highest of the alternate fuels discussed.

ETBE has an unpleasant odor. I was unable to breath the vapors long enough to get a headache.

ETBE is partially renewable. Possibly totally renewable if made with swamp gas as well as methanol.

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■ **Knock Testing (AC 33-47)**

- Ambient Conditions:
 - » 103 °F, Low Humidity
- Engine Conditions:
 - » At Maximum CHT (1), Others within 25 °F
 - » Oil up to Maximum Temperature
 - » Demonstrate up to 15 % lean without knock
- Dynamometer is Easier to Control

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19

This Advisory Circular describes the requirements for meeting FAR 33.

If the engine is set up to operate lean of stoichiometric, then further leaning takes you away from knock, which is most severe near stoichiometric. If the engine is set up for lean operations, the engine must operate lean of stoichiometric at all altitudes.

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■ **Knock Testing (cont.)**

- What is Knock
- Knock Systems
 - » Vibration Pick-ups
 - » Pressure Transducers
 - In Cylinder
 - On Spark-plug
 - » Cessna System
 - Available from Lou Zagst 716-684-0001

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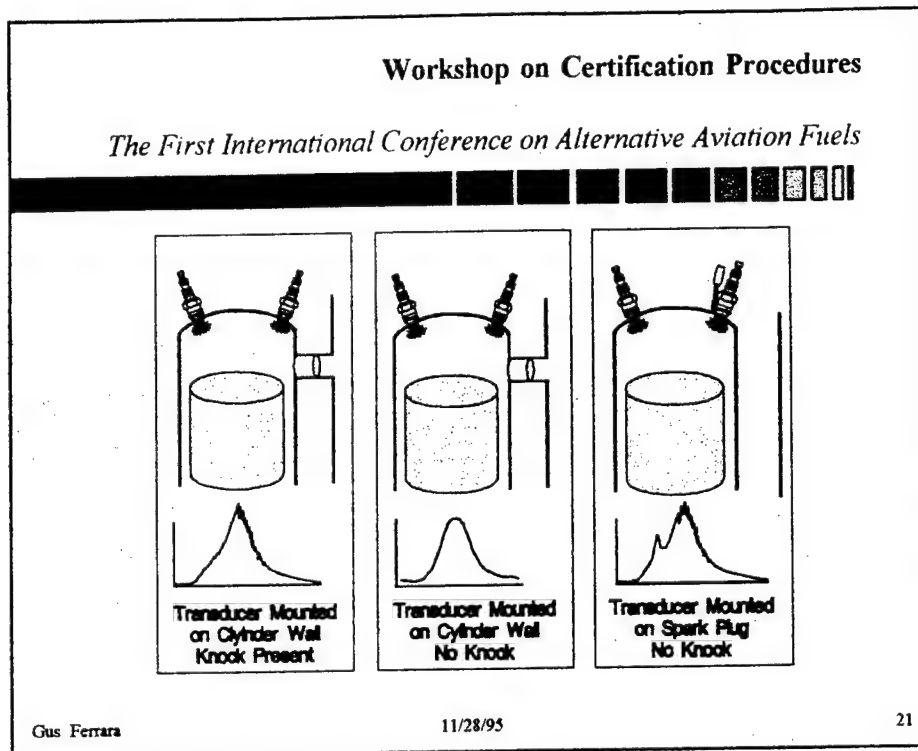
20

Knock is spontaneous combustion in the cylinder. The knock sound you hear is the shock wave traveling back and forth through the cylinder. Typically knock cannot be heard in cockpit.

Knock is different from pre-ignition. Pre-ignition is when burning occurs without the spark. Knock occurs after the combustion process has started.

Three basic systems for detecting knock:

- Vibration Pickups have been used since WW II. Typically mounted on the spark plug. The operator needs special training.
- Pressure Sensors are relatively new (fast response) and they can be mounted in the cylinder wall or on the spark plug. If mounted on the spark plug or in a remote chamber on the cylinder wall, expect noise. Flush mounting with the cylinder wall is best.
- The system developed by Cessna uses washers that sense the pressure in the cylinder and the signal is processed to give a number. (PCB Peizotronics is the vendor)



Note if the pressure transducer is not flush mounted, you will get noise like on the spark plug installation. The pressure transducer should be water cooled to preserve life. This limits use in flight testing, but probably best for dynamometer testing.

In spark plug mounted system, the flame front shows up as a spike on the up-slope.

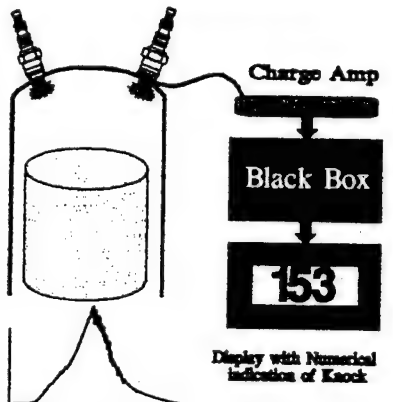
Note, the knock typically occurs after peak pressure in aircraft installations.

Knock will result in CHT rise and higher oil temperatures over time. The rate of change depends on the severity of knock. In some cases light knock will occur and the temperatures will not change. This is not considered knock for certification purposes.

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■ **Knock Testing (cont.)**

- Cessna System
 - » Strain Washer
 - » Charge Amplifier
 - » Filters
 - » Numerical Display
 - » Option for Raw Signal
 - » Washer & Charge Amps on Cold Side of Engine



Gus Ferrara 11/28/95 22

In the Cessna System, the strain washer and the charge amplifiers are mounted in the cowling/nacelle. They are placed on the cold side of the engine.

Automotive style knock sensors are vibration pick-ups mounted on the engine block. There are several problems associated with using these systems:

- The aircraft engines operate hotter and the transducers are not suitable for these temperatures.
- Aircraft engines have split cases and separate cylinders, which affects the signal reception.
- Aircraft cases are made of aluminum, which suppresses the signal strength.

**STRATEGY SESSION: COMMERCIALIZING ALTERNATIVE
FUELS IN THE AVIATION SECTOR**

PANEL DISCUSSION

**BILL HOLMBERG, PRESIDENT, AMERICAN BIOFUELS ASSOCIATION
(FACILITATOR)**

GUS FERRARA, INDEPENDENT CONSULTANT

**PHIL LAMPERT, PROJECT COORDINATOR, NATIONAL ETHANOL
VEHICLE COALITION**

**JOHN RUSSELL, DIRECTOR, ALTERNATIVE FUELS UTILIZATION
DIVISION, U.S. DEPARTMENT OF ENERGY**

**MAX SHAUCK, DIRECTOR, AVIATION SCIENCES, BAYLOR
UNIVERSITY**

**RUSSEL SMITH, EXECUTIVE DIRECTOR, TEXAS RENEWABLE
ENERGY INDUSTRIES ASSOCIATION**

**CLAY WILKINS, DIRECTOR, AEROSPACE TECHNOLOGIES, TEXAS
STATE TECHNICAL COLLEGE**

**FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS**

NOVEMBER 2-4 1995

BAYLOR UNIVERSITY

Summary of the Strategy Session to Commercialize Alternative Fuels in the Aviation Sector

This strategy session, which took place on the day before the conference, was designed to elicit advice on how to take the work on ethanol as an aviation fuel out of the realm of research and into the market place. It was also hoped that people attending the session would be motivated to use the commercialization strategy developed as the blueprint for future actions. For this reason, the outline for a commercialization strategy was passed out to the audience at the start of the session and audience members were asked to comment on the outline at the end of the conference. (See attached copy of outline.) Also passed out were copies of slides used by the session facilitator, Bill Holmberg, president of the American Biofuels Association.

Bill Holmberg started the session by introducing the first speaker, Dr. Max Shauck, Chairman of the Aviation Sciences Department at Baylor University and Director of the Renewable Aviation Fuels Development Center (RAFDC). During the introduction, Holmberg mentioned the important contributions that Grazia Zanin (Dr. Shauck's wife) has made to the success of RAFDC and the Baylor program and the extremely long hours that Glenn Maben has put in over the last several months in order to keep the planes flying and get the testing underway. Holmberg also said that Dr. Shauck's work is the foundation on which the commercialization effort will be built and then asked him to describe his work.

Dr. Shauck talked about his motivation for working on alternative aviation fuels, noting that during the oil embargo of the early 1970s, general aviation had been threatened with rationing and the possibility that there would be no fuel allocated to private aircraft. He then described the history of his work at Baylor University. He listed the programs accomplishments, touching on the various record setting flights he had made using alcohol fuels, his first (unsuccessful) attempt to cross the Atlantic using alcohol fuels, as well as the successful transatlantic flight he had made with his wife Grazia (for which he received the Harmon Trophy). He also talked about getting FAA certification of the Lycoming IO-540 and the O-235 engines on ethanol and the ongoing work to certify the Cessna 152 and the Piper Pawnee airframes.

After Dr. Shauck's remarks, Bill Holmberg described the difficulties he had in getting fuel to Dr. Shauck during his transcontinental flight. Holmberg then introduced Clay Wilkins, a former Air Force fighter pilot and Director of the Texas Department of Aviation, who was, at the time of the conference, the Director for Aerospace Technologies at Texas State Technical College.

Wilkins started his comments by taking the opportunity to thank the various organizations, including Chrysler Technologies Airborne Systems, which had contributed to the conference. He then stated that his views were based, not on any great knowledge of alternative fuels, but rather on his experience as a user of aircraft since he was 11 years of age. He stressed the significance of air transportation to the U.S. economy and its competitive ability in the world. He talked about the folly of relying on oil imported from the Middle East and the importance of working to reduce that dependency. He also said that he could not understand why the last two Texas Secretaries of Agriculture had not supported this effort. He then noted that, while general aviation has to work to promote the use of alternative fuels, it does not have the influence that the agricultural sector does and, therefore, there is a need for agriculture to promote the

commercialization of ethanol as an aviation fuel in a big way. He concluded by saying that it made no sense to pay farmers not to grow crops when we could pay them to grow energy feedstocks.

After Clay Wilkins had finished, Bill Holmberg told a story about the time Dr. Shauck had done an airshow for Vice President Bush. He then introduced Russel Smith who is the Executive Director of the Texas Renewable Energy Industry Association (TREIA) and who had founded the Texas Solar Industries Association. (TSIA)

Russel started by saying that he had been working with renewable energy since 1976 and had seen a lot in that time. He pointed out that in Texas during the 1970s there had been attempts made to bring ethanol and other renewable fuels on line and that these attempts had failed due to lack of support at the policy level. And, while this had been a disappointment at the time, it was not a permanent defeat. One of the problems had been that the renewable energy community was viewed as a bunch of crazies, who, overcome by enthusiasm, had promised much more than could be delivered. What needed to be done was to take a more realistic long term view and find a way to work with the policy makers.

Russel pointed out that there have been a number of major changes since the 1970s, one of the most important of which is the fact that Texas is now a net energy importer. According to him, there are now compelling reasons for pursuing renewable fuels: Clean Energy and Texas Jobs. He noted that the environmental situation in Texas, like the rest of the country, is on decline and stated that for this reason clean burning renewable fuels will supplement, and gradually replace, over time, fossil fuels. But, he said, if it is not making money it is not going to get done. So for commercialization of ethanol as an aviation fuel, the first issue is getting the cost down. If a fuel works as well as another fuel and cost less, somebody is going to use it.

Russel recognized that new technology is reducing the cost of ethanol, but noted that the price may not be falling fast enough and, therefore, there may be a need for state support. However, he said, the state government is not going to promote an alternative fuel unless it does something for the state. For example, if it can be shown that the feedstock for aviation fuels produced in Texas refineries is imported, than it makes sense to replace that fuel with a fuel whose feedstocks are made here. He went on to say, that maybe there is a way to account for the environmental cost of the existing fuels and the benefits to be gained by replacing them.

Russel Smith concluded by saying that he thinks that, if we can get this type of mind in place for the decision makers and the end users, then the doors will open.

At the end of Smith's comments, Holmberg followed up on his theme and described how Fred Potter (President of Information Resources, Inc.) and Todd Sneller (Administrator of the Nebraska Ethanol Board), who were in the audience, had started out as "crazies", but then had started working with people from the auto industry and the petroleum industry and now were making things happen. Holmberg also commented that the main obstacle to commercialization efforts is lack of funding.

Holmberg then went on to introduce Gus Ferrara, an independent aviation consultant, who had been an FAA researcher for many years.

According to Ferrara, the big concern is "can we go ahead and certify a fleet of aircraft?" He pointed out that it has already been done and that the auto gas certification program provides an example of how to do it. He noted that there are technical questions that have to be addressed before commercialization of a fuel. Is the fuel dangerous or toxic? Does it require special handling? He pointed out that these issues are addressed in the certification process and ran through the certification procedures and how these procedures address safety issues. He recommended that once you have a few planes certified you need to set up a small fleet and run it for a few years to make sure that real world data matches expectations and there are no unexpected problems, such as corrosion. Only then, he said, should you start to commercialize the fuel. He ended by suggesting, that at this point, to build enthusiasm for the fuel you might give away free samples.

Bill Holmberg followed Ferrara's statements by noting how valuable Ferrara had been when he was with the FAA, in providing funding and support. He noted that the next speaker, Phil Lampert had been very important in supporting the use of ethanol in automobiles, pointing out that Phil, who is Project Coordinator for the National Ethanol Vehicle Coalition, had worked as the Deputy Director of the Missouri Department of Natural Resources and Energy, where he played a key part in the formation of the Governors' Ethanol Coalition (GEC).

Phil proceeded to describe the background of the E85 program, which was established by the National Corn Growers and GEC to coordinate their efforts to promote the use of E85. He stated that today there are nearly 700 E85 cars across the U.S. and that in a year there will be over 120,000. According to him, the Ford Taurus and all General Motors 4-cylinder pickups will be available as E85 vehicles next year. He predicted that E85 is going to be the fuel of choice for passenger cars but, not for medium and heavy duty trucks.

He explained that the National Corn Growers are supporting E85 because it improves farm income and noted that, contrary to some claims, the production of ethanol does not take food out of mouths of babies. He reported that between 400-500 million bushels of corn are used to produce ethanol every year. And, he said that the National Corn Growers supports the use of cellulose to make ethanol because the farmers are expected to be the ones growing the feedstocks if that happens. According to Lampert, about \$1 million dollars has been pledged to the E85 program, which will be used to establish a minimum of 40 refueling stations in 11 states. He also noted that there is a lot of interest in this program in other states. He believes that this provides an opportunity for ethanol in aviation, because, as a result of the E85 Program, there will be high levels of ethanol around. He commented, that, if the fuel is available we might as well use it for aviation. Lampert closed by saying that it is commitment, political force and the financial resources that will make the E85 program a success.

At the conclusion of Phil Lampert's speech, Bill Holmberg continued his recognition of people who have helped to advance the ethanol industry by pointing out Bill Wells, of Delta-T, Inc., and Bob Harris, of the Nebraska Energy Office. He then called Plino Nastari out of the audience and asked him to give a short report on the Brazilian ethanol program.

According to Mr. Nastari, Brazil has had great success with its ethanol program, but has had a hard time telling the world about it. If it were not for Fred Potter and IRI, there would be very little knowledge about Brazil's ethanol program in the United States. He said that there are 4.3 million neat ethanol cars (35% of fleet) and 25,000 fueling stations for neat ethanol in Brazil. And, as a consequence, Brazil's ethanol use is the equivalent of 215, 000 barrels of gasoline per day.

Mr. Nastari proudly stated that Brazil has had to overcome many problems to get to this point and has learned a lot in doing so. He thought it would be of interest to the U.S. ethanol industry to know that the Brazilians have been transporting ethanol in the same pipelines that they use to transport gasoline without the use of pigs and with no resulting problems (which has not been able to get U.S. pipeline companies to agree to transport ethanol through their pipelines.)

Plino stated that the Brazilian government supported the ethanol program because in Brazil they have recognized the competitive factors other than market prices. Brazilian ethanol is competitive when the price of oil in Rotterdam is between 19 and 21 dollars per barrel. They have done these calculations using methodology developed by the world bank. He went on to comment that the fact that there is a U.S. subsidy for ethanol is merely translating to market prices ethanol's benefits.

Looking to the future, Mr. Nastari said that the major thing that changes the situation with respect to clean fuels is the climate convention signed in Rio de Janeiro because the climate convention gives us a way to internalize the hidden environmental benefits of ethanol fuels.

Mr. Nastari ended his remarks on a positive note, saying Brazil is leading today, but I don't think we will be leading for too long once the U.S. gets going. He also said that he had recently been to Tokyo for the meeting of the World Energy Council and at that meeting, the president of Shell Oil had defended biomass energy. According to Plino, this meant that Shell was positioning itself as an energy company, not an oil company.

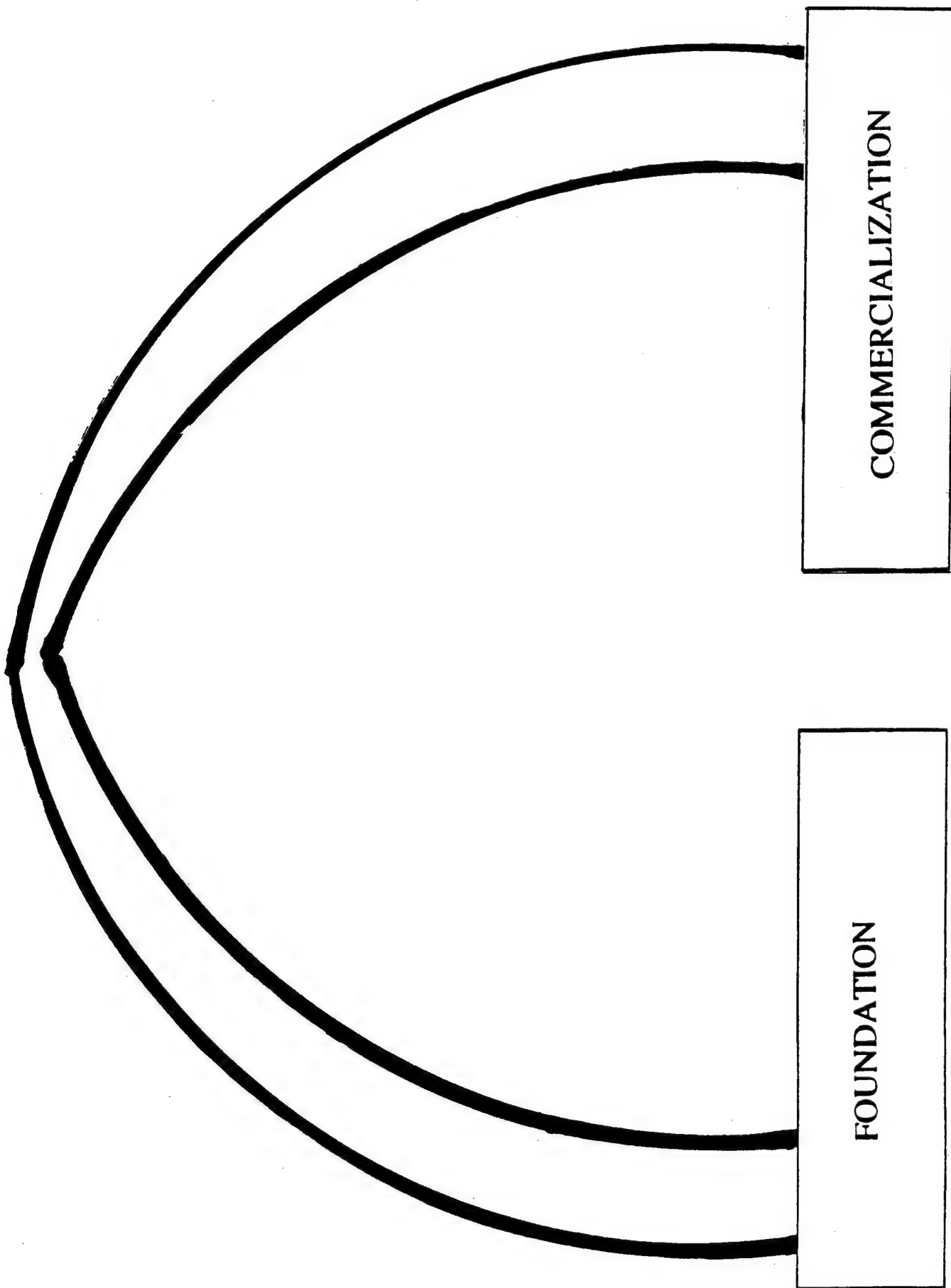
Bill Holmberg followed Plino Nastari's remarks with a list of next steps to be taken. First and foremost among them was getting funding. The other steps were to hire more people and to develop proposals and a business plan. He also noted that some years ago he had made a speech to a group of international economists proposing the development of a way to quantify the externalities associated with fuels use.

Next, Bill Holmberg introduced John Russell, Director of the U.S. Department of Energy's Office of Alternative Fuels and a former Air Force pilot, who described DOE's "Clean Cities Program". According to Russell, this program has organized fuel suppliers and fleet operator in 41 cities to work together to coordinate the procurement of alternatively fueled vehicles (AFV) and to establish the needed refueling infrastructure. The purpose of this program is to get around the chicken and the egg problem of no one being willing to purchase an AFV unless they can refuel it and no one being willing to invest in alternative fuels infrastructure until there are vehicles which would make use of it.

What John Russell proposed is the establishment of a "Clean Airports Program" which would be modeled on the "Clean Cities Program". He noted that the fleet of aircraft owned by a FBO is a fleet just like any other fleet of vehicles. He stated that DOE will be glad to work to develop this idea further.

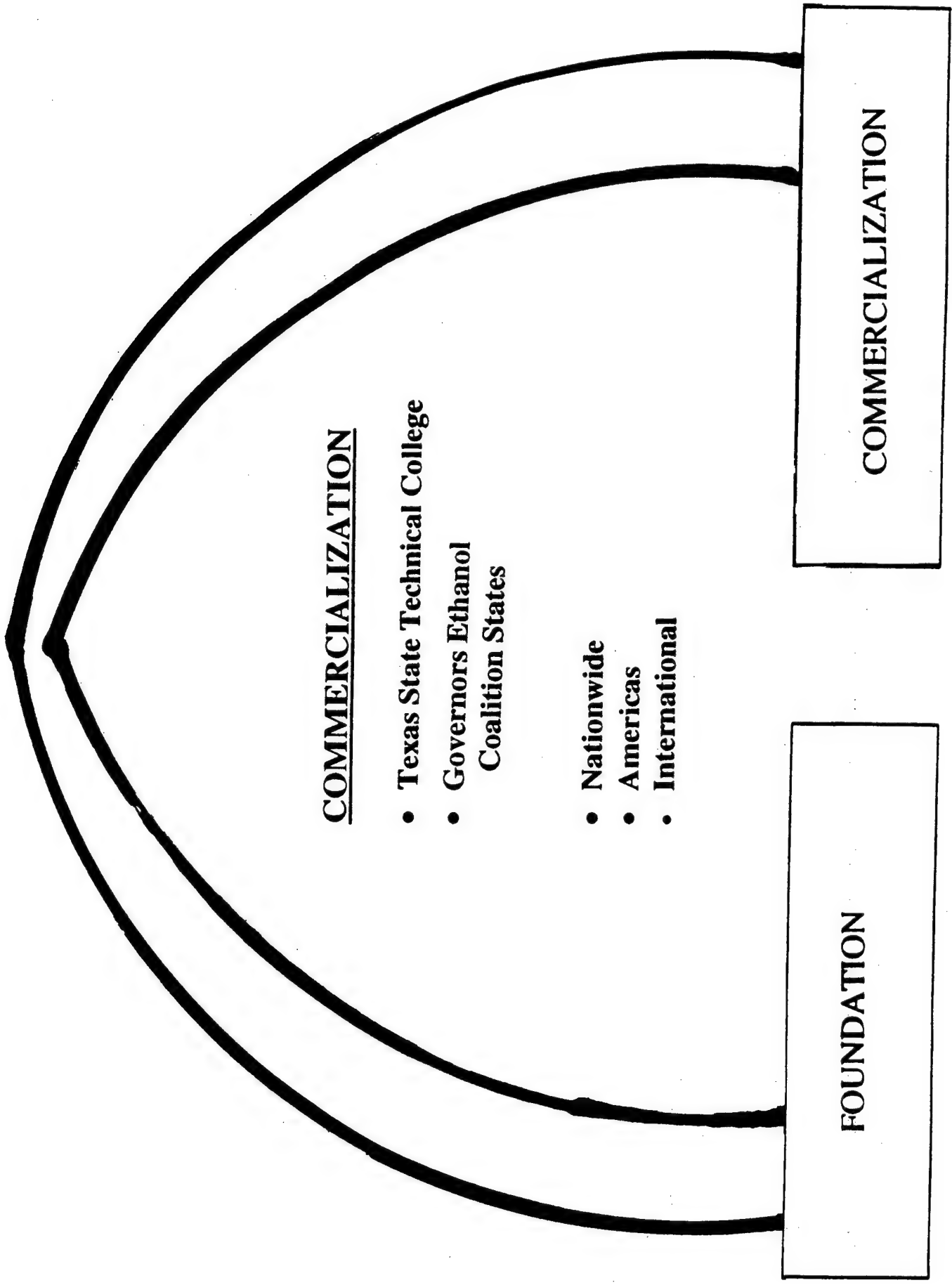
Holmberg next showed a slide on the phases of the commercialization process, and how by starting with the fleet of aircraft at Texas State Technical College, the effort should be expanded to include aircraft owned by the states that make up the GEC, the country and then the world.

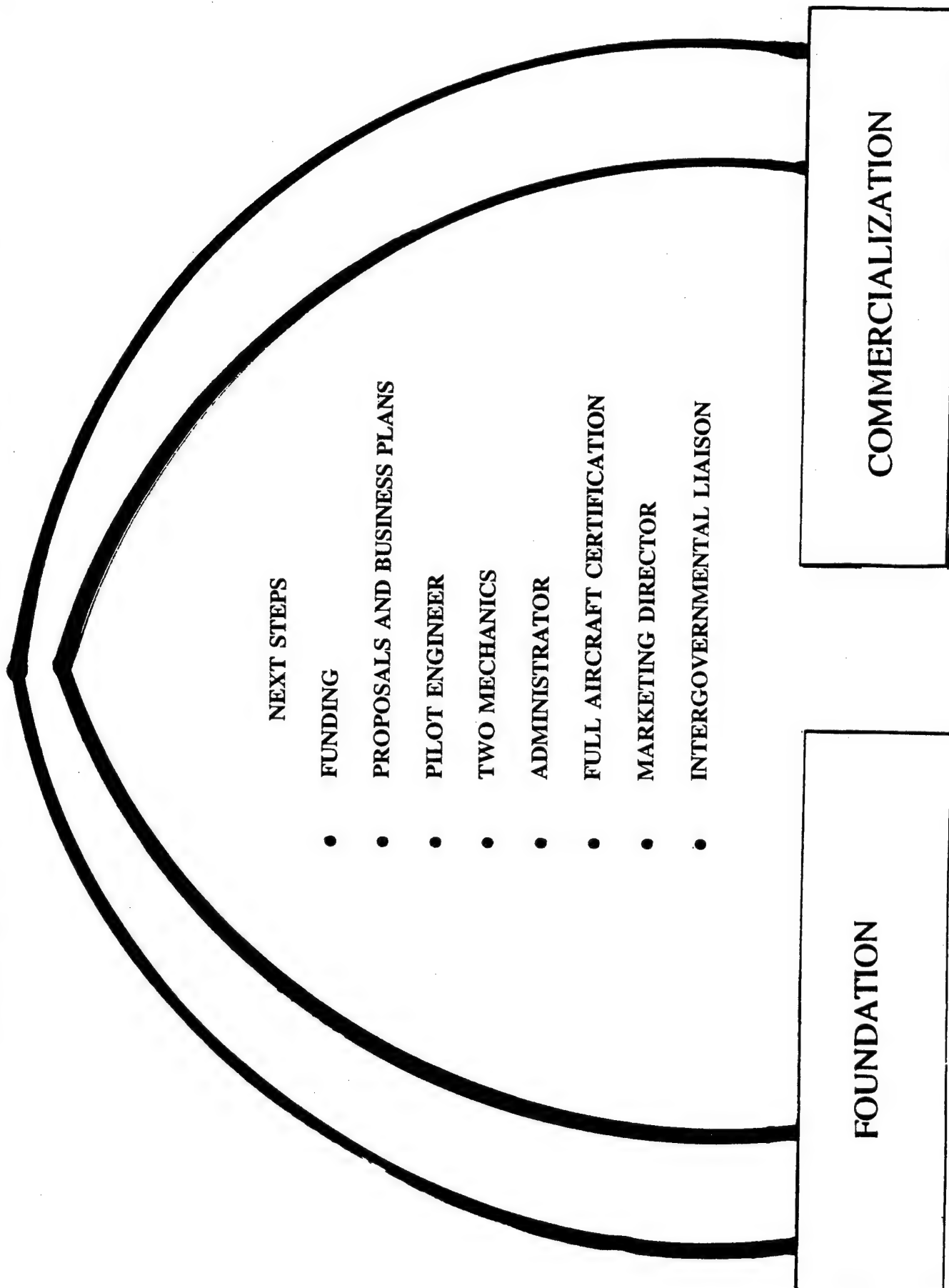
At this point Holmberg opened the forum to questions. The only question asked from the audience was, what is the major impediment to moving forward with alcohols for aviation use? Max Shauck's answer was, "Money. Funding. Glenn Maben and all of the RAFDC's team are working 24 hours a day, we are replacing massive amounts of money with time. Its difficult to get the word out in the U.S. Its easier in other countries." John Russell's answer was, "Convenience. Fossil fuels are so convenient and we are so spoiled." Bill Holmberg's answer was, "As of right now the oil companies own the aviation market place. They aren't going to give that up lightly. So we need to take a page out of Fred Potter's book and team up with those people so that marketplace is shared in a way that makes sense to them."



FOUNDATION

- 1980 --Develop and fly test engine modifications for Bellanca Decathalon. First flight on 180 proof ETOH.**
- 1983 --First coast to coast on ETOH.**
- 1984 --Modify and flight test Pitts Special on 50/50 ethanol/methanol.**
- 1986 --Modify and flight test twin-engine Piper Aztec on 50/50.**
- 1987 --First transatlantic attempt in Aztec 50/50; Russell/Shauk, unsuccessful.**
- 1988 --Modify and test Italian Siai Marchetti on 200 proof ETOH.**
- 1989 --Modify and test Velocity on 200 proof ETOH. First transatlantic flight on ETOH Zanin/Shauk.**
- 1989 --First F.A.A. certification on non-petroleum fuel for a series of engines on 200 proof ETOH--fuel injected 260 H.P.**
- 1991 --Second F.A.A. Certification on a series of engines on ETOH--a carburated 105 H.P.**
- 1992 --Establishment of R.A.F.D.C. First flight test of Cessna 152 on ETOH.**
- 1993 --First set of flight tests on Ag plane -- Piper Pawnee.**
- 1995 --First flights on ETBE. First public demonstration on ETBE at Paris Airshow.**





DEVELOPMENTS IN AVIATION FUEL

BRENT BAILEY
NATIONAL RENEWABLE ENERGY LABORATORY
GOLDEN, COLORADO

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Developments in Aviation Fuel Properties

Brent Bailey



**National Renewable Energy Laboratory
Golden, Colorado**

**The First International Conference on Alternative Aviation Fuels
November 3, 1995
Baylor University
Waco, TX**

P194-B056601

Introduction

Fuel Properties = Aircraft Performance

Throughout aviation history, a wide variety of fuels have been used. Advances in fuel technology in concert with engine developments have lead to increased power, range, durability, and safety. In the final analysis for a fixed engine technology, fuel properties determine aircraft performance.



Overview

- History of aviation fuel development
- Critical aviation fuel specifications
- Comparison of several alternative fuels



The Wright Flyer—1903

- Engine—4.4:1 compression ratio, fixed 1200 rpm, 12 hp
- Fuel tank—half-gallon gravity feed
- Fuel—distilled from paraffinic Pennsylvania crude oil; octane number estimated to be 38



World War I—1917

- U.S. Grade X fuel not acceptable in Europe (octane 45–55)
- French and British engines developed on fuels from aromatic crudes (octane 70)
- 1918 first U.S. aviation fuel specification domestic, export, fighting grades
- 1922 U.S. specifications, included gum limits
- Detonation discovered by Gibson in 1915, explained by Ricardo in 1923



The Spirit of St. Louis—1927

- Lindbergh used California gasoline
- 500 gallons shipped to Roosevelt Field, Long Island
- Octane number estimated at 70
- TEL discovered in 1921 by Midgley and Boyd but deposits not solved until about 1927
- Waukesha octane engine used in 1929



World War II

- Frank Klein, test pilot and lab director at Wright Field, presented paper in January 1935 showing 40% increased rate of climb with 100 octane fuel
- 100 octane flight testing began in 1935 when 300,000 gallons delivered under U.S. Army Air Corp contract
- F.R. Banks of Ethyl Export Corp presented paper in England 1937 on 100 octane aviation gasoline
- Decision made in 1937 to develop Rolls-Royce and Bristol radial engines to take full advantage of 100 octane fuel
- Supply dependent on U.S., rich mixture requirement added by British; power increased by 30%



The Battle of Britain*

The RAF fighters, outnumbered almost three to one by the Luftwaffe, won the Battle of Britain by a narrow margin, as most military historians can testify. Had the Luftwaffe gained control of the air, Hitler would have proceeded with "Operation Sea Lion" and the then vastly superior German military forces could most probably have invaded England successfully. With Britain occupied, it is difficult to conceive how a subsequent invasion of Europe could have been accomplished to defeat Nazi Germany.

*Ogston, SAE Paper No. 810848

ASTM D 910-89 Aviation Gasoline Specification

Properties

| | Grade 100 LL |
|---------------------------------------|---------------------|
| Knock value (lean/rich, min.) | 100/130 |
| Color | Blue |
| TEL (ml/gal, max.) | 2.0 |
| Distillation (°F, 10%/50%/90%, max.) | 167/221/275 |
| Net heat of combustion (Btu/lb, min.) | 18,720 |
| Vapor pressure (psi, min./max.) | 5.5/7.0 |



ASTM D 910-89 Aviation Gasoline Specification

Properties (cont.)

Grade 100

| | |
|---------------------------------------|-------|
| Copper strip corrosion (max.) | No 1. |
| Potential gum (mg/100 mL, max.) | 6 |
| Sulfur (wt%, max.) | 0.05 |
| Freezing point (°F, max.) | -72 |
| Water reaction (mL, vol. delta, max.) | 2 |
| Antioxidants (lb/1,000 bbl, max.) | 4.2 |



Automotive Gasoline Unsuitable for Aviation Use*

- Different octane ratings
- Wider distillation range
- Higher vapor pressure
- Automotive TEL may have excess bromine
- Poorer long term stability
- Solvent characteristics not suitable
- Higher contamination levels

*Boldt and Hall in ASTM STP 7C

P184-B056611



Essentials of Alternative Aviation Fuels

- Minimum knock value
- Controlled volatility
- Storage and handling stability
- Material compatibility
- No contamination
- Favorable heating value



Alternative Fuel Knock Values

| | |
|-----------|-----------------------|
| Avgas | 100* |
| MeOH | 112 |
| EtOH | 112 |
| MTBE | 99 |
| ETBE | 101 |
| CNG | 115 |
| LPG | 97 |
| Biodiesel | >20 (Cetane No. = 52) |

* Lean performance number, all others approximate motor octane number



Alternative Aviation Fuel Volatility

| | Distillation (°F, 10%/50%/90%) | Vapor Pressure (psi) |
|--------------|-----------------------------------|-------------------------|
| Avgas (max.) | 167/221/275 | 5.5– 7.0 |
| MeOH | 149/___/___ | 4.6 |
| EtOH | 172/___/___ | 2.3 |
| MTBE | 131/___/___ | 7.8 |
| ETBE | 161/___/___ | 4.4 |
| CNG | -258 /___ /___ | 3,000 |
| LPG | -44 /___ /___ | ~100 |
| Biodiesel | 320/335/345 | 0 |

P194-B056614



Alternative Aviation Fuel Stability

| | |
|-----------|------------------|
| Avgas | Meets ASTM D 910 |
| MeOH | Good |
| EtOH | Good |
| MTBE | Good |
| ETBE | Good |
| CNG | Good |
| LPG | Good |
| Biodiesel | Poor |



Alternative Aviation Fuel Material Compatibility

| | |
|-----------|---------------------------|
| Avgas | Demonstrated performance |
| MeOH | Potential problems |
| EtOH | Potential, less than MeOH |
| MTBE | Unknown |
| ETBE | Unknown |
| CNG | Okay |
| LPG | Okay |
| Biodiesel | Potential problems |



Alternative Aviation Fuel Energy Content

| | Net Heating Value (Btu/lb) | Density (lb/gal) |
|--------------|-------------------------------|---------------------|
| Avgas (min.) | 18,720 | 6.0 |
| MeOH | 8,600 | 6.6 |
| EtOH | 11,600 | 6.6 |
| MTBE | 15,100 | 6.2 |
| ETBE | 15,630 | 6.2 |
| CNG | 20,550 | 1.2 |
| LPG | 19,860 | 4.5 |
| Biodiesel | 16,300 | 7.3 |



Conclusions

- Fuel properties determine aircraft performance
- Fuel technology can have huge impacts
- Current specifications simple yet tightly controlled
- Alternative aviation fuels must have
 - Minimum chemical combustion quality
 - Controlled volatility for fuel system
 - Stable storage and handling
 - Compatibility with fuel system
 - Favorable heating value
 - No contamination

AVIATION GASOLINE SITUATION: CURRENT SEARCH FOR
PETROLEUM ALTERNATIVES TO AV-GAS

DOUG MACNAIR
DIRECTOR
GOVERNMENT AND TECHNICAL AFFAIRS
AIRCRAFT OWNERS AND PILOTS ASSOCIATION

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Aviation Gasoline

**Current Search For
Petroleum Alternatives
To AvGas**



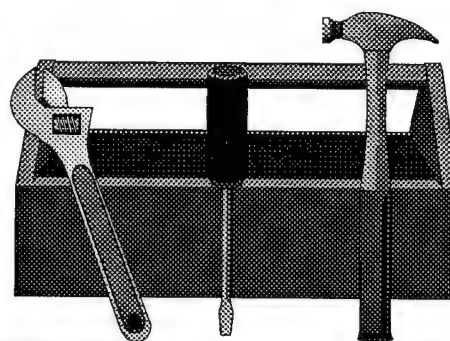
General Aviation Fuels

- 100LL - High Octane Leaded Aviation Gasoline
- Autogas - Low Octane Unleaded Automotive Gasoline
- Jet A - Turbine Fuel

Two major efforts...

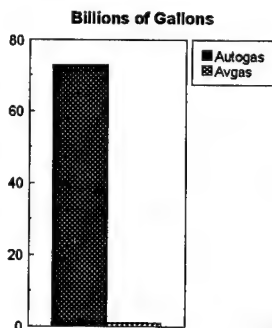
- Find a high octane unleaded replacement for 100LL
 - Driven by environmental concerns
- Develop low-cost alternative for low octane aircraft
 - Driven by economics

Background Information High Octane program



Annual U.S. Gasoline Production

- Avgas - 350 million gallons
- Autogas - 73 billion gallons

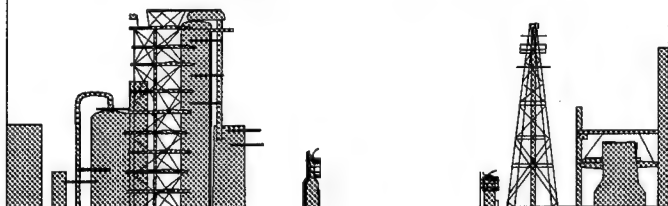


Leaded Gasoline Problems

- Environmental Considerations
 - Regulation
- Distribution Difficulties
 - Dedicated transport
 - Low volume
 - Widely dispersed points of sale
- Occupational Safety

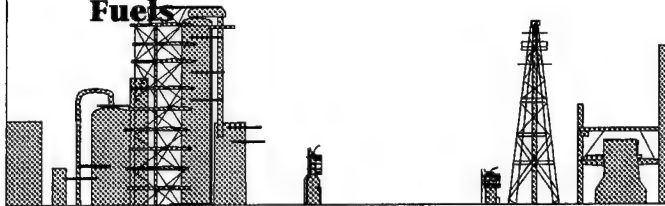
1990 Clean Air Act Amendments

- **U.S. Congress Passes Mandate to Clean Up the Air in the U.S.**
- **U.S. EPA Develops Regulations to Meet Ambient Air Standards Set by Congress**



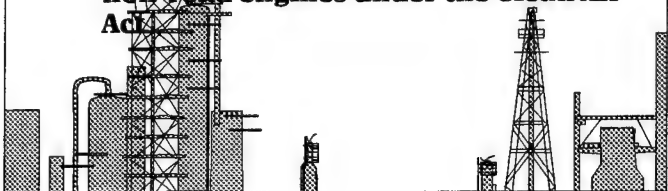
Environmental Regulations Include:

- **Ban on Production of Lead Burning Non-Road Engines**
 - Aircraft were believed to be included in this ban
- **Ban on Leaded Motor Vehicle Fuels**



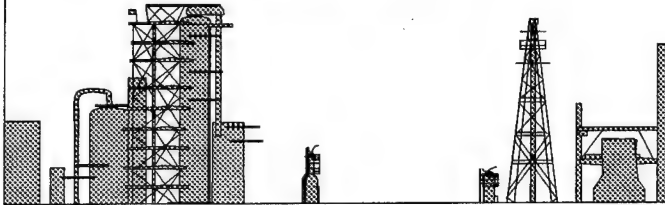
The Temporary Solution

- **Coordinated Opposition**
- **Legal Interpretation**
 - FAA has sole authority over aviation safety matters
 - Aircraft engines are not considered non-road engines under the Clean Air Act



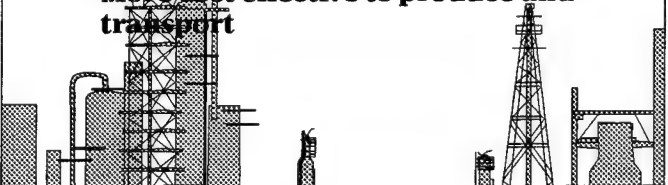
Bottom Line...

- **EPA Still Has the Authority to Regulate Aircraft Emissions at Some Future Date**
- **No Immediate Plans To Regulate General Aviation Fuels**



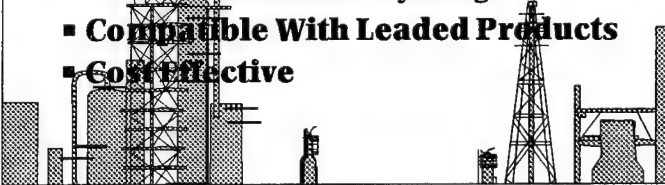
Market Forces Still Drive the Need for Unleaded Fuel Development

- **Environmentally Acceptable**
- **Commonality with Other Readily Available Fuels**
 - More cost effective to produce and transport



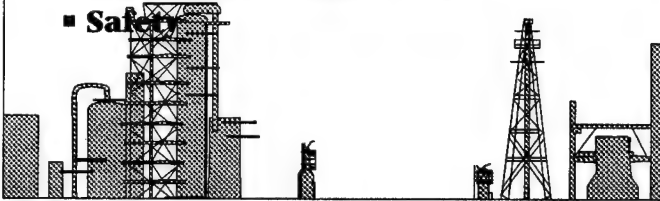
Unleaded Fuel Considerations

- **Meet the Needs of the Existing Piston Aircraft Fleet**
 - Little Or No A/C and Eng. Modification
 - Minimal Recertification
 - No Significant Reduction in Performance or Safety Margins
- **Compatible With Leaded Products**
- **Cost Effective**



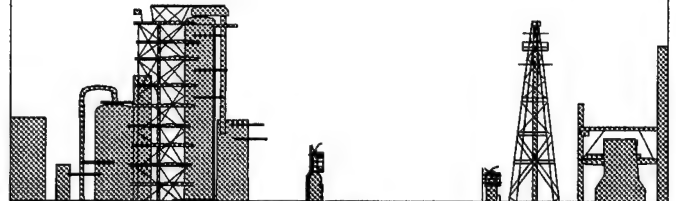
Needs of Existing Fleet

- Octane
- Energy Density
 - Range
 - Power
- Materials Compatibility
- Safety



What is aviation octane?

- Three types of octane
 - Research Octane
 - Motor Octane
 - Aviation Octane



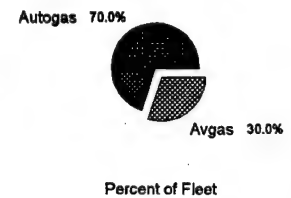
What are the differences

- Autogas Uses $(R+M)/2$ (average)
- Aviation is similar to Motor Octane
- 100 Aviation Octane = nearly 108-112 octane autogas
 - Most autogas does not exceed 94 octane (85 aviation octane)

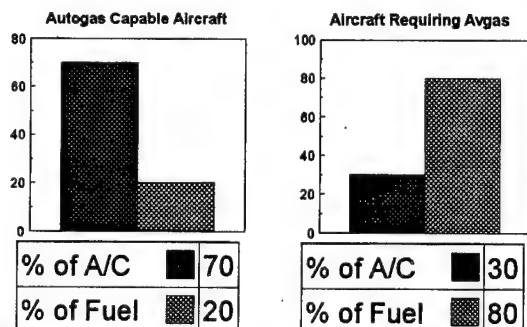


Autogas or Avgas?

- Autogas is readily available
- Autogas would serve the needs of the majority of existing aircraft



Where Does The Fuel Really Go?



A Replacement For 100LL Must Be Developed Soon!

- To serve the real needs of the existing fleet
- To be ahead of future environmental regulation
- To ensure continued revival of the general aviation manufacturing industry



Who Is Participating?

- Federal Aviation Administration
- Major Petroleum Producers
- Airframe and Engine Manufacturers
- American Society for Testing and Materials
- Coordinating Research Council
- Colleges and Universities

What is Being Done?

- Research On High Octane Unleaded Fuels
- Testing of Unleaded Fuels on Existing Engines
- Preliminary Materials Compatibility Testing

Major Hurdles...

- Octane, octane, octane!!
- Energy Density
- Toxicity
- Cost

Where are we Today?

- 97 octane unleaded fuels have been produced and tested
- 100 to 104 octane has been achieved in the laboratory but there could be some compromises
 - Cost?
 - Emission Point?

Potential Additives and Blend Stocks

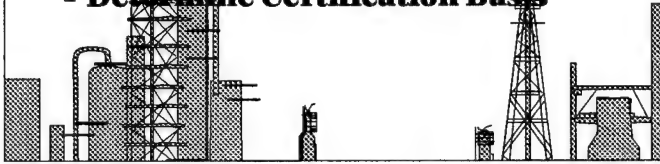
- Oxygenates
 - MTBE (Methyl Tertiary Butyl Ether)
 - ETBE (Ethyl Tertiary Butyl Ether)
 - Ethanol
 - Methanol
- Amines
- Metals
 - MMT (Manganese)

The Next Step...

- Determine the actual octane needs of the existing fleet
- Perhaps a compromise can be reached between octane and cost
- Test highest octane economical fuel

Still To Be Accomplished...

- Cost Analysis of Varying Blends
- Ground and Flight Testing
- Materials Compatibility
- Compatibility with Leaded Fuels
- Write Standards
- Determine Certification Basis



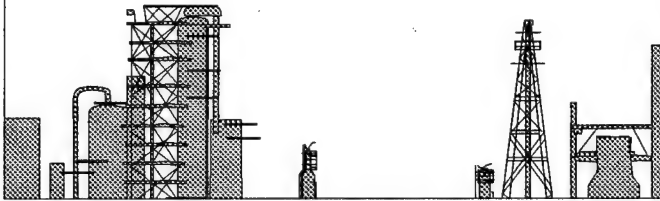
How Do We Proceed?

- There is currently no hard deadline
- Environmental pressure is increasing
- Regulation must be minimized while progress continues

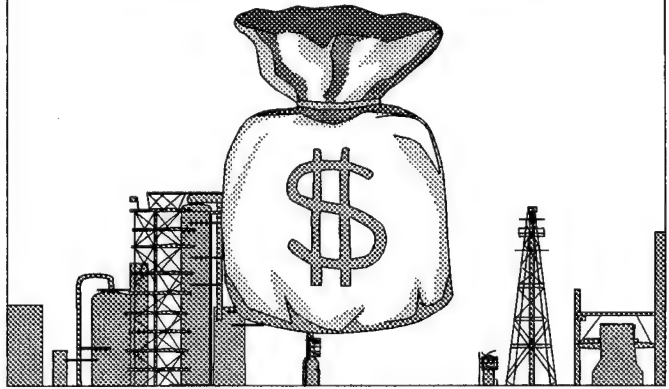


The Big Question...How Long?

- Minimum of 10 years
 - 6-7 years of continued testing
 - 2-3 years to develop standards
 - 2 years of aircraft certification



Low octane alternative



Interim Steps

- Development of ASTM 82UL Specification
 - Based on autogas
 - For new production aircraft
 - Could serve interim needs of a large percentage of the existing fleet
 - Show progress to environmental regulators



**FUEL SUPPLIERS' RESPONSE TO ALTERNATIVE FUELS
PANEL DISCUSSION**

TODD SNELLER, NEBRASKA ETHANOL BOARD (FACILITATOR)

JERREL BRANSON, PRESIDENT, ECOGAS CORP.

CHUCK MINARD, REGIONAL ACCOUNT MANAGER, CONOCO

FRED POTTER, PRESIDENT, INFORMATION RESOURCES INC.

RICHARD RILEY, RESEARCH ASSOCIATE, PHILLIPS PETROLEUM CO.

**FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS**

NOVEMBER 2-4 1995

BAYLOR UNIVERSITY

Summary of The Fuel Suppliers Response to Alternative Fuels Panel

Jerrel Branson, President and CEO of Ecogas Corporation; Chuck Minard, Regional Account Manager for Conoco, Inc.; Richard Riley, Research Associate in the Fuels and Lubricants Branch of Philips Petroleum; and, Fred Potter President of Information Resources, Inc., all participated in this panel discussion which was led by Todd Sneller, Administrator of the Nebraska Ethanol Board.

After some brief introductory remarks, Todd Sneller started out by asking Jerrel Branson to comment on the infrastructure issues effecting the use of alternative fuels. Mr. Branson replied that his views on this issue result from his work to place natural gas vehicles in the market and that he believes that for a new fuel to succeed it has to be as transparent as possible when compared to the existing fuel. In terms of performance, fuel handling, and refueling times, the new fuel has to be equivalent to the existing fuel and it must also offer better economics. A new fuel will be successful because of economics and not because of federal or state mandates.

Mr. Branson continued, saying that the important issues were energy density, weight of the fuel, and sacrifice of usable volume. On this basis, he claimed that liquefied natural gas (LNG) does well -- giving as an example the conversion (in the Soviet Union during the early 1970s) of both helicopters and the Soviet version of the Boeing 707 to use LNG. However, he did admit that there are problems in using natural gas when it is stored by compression in aircraft.

Todd Sneller then turned to Chuck Minard and asked him which alternative fuels, if any, might replace 100 octane leaded Avgas (100LL), and on what time scale this replacement would take place. Mr. Minard replied that, because of the cost and complication associated with lead in Avgas, some refiners have already started to cut production and to reduce its distribution over pipelines. This demonstrates that the closer any replacement fuel is to unleaded motor gasoline the better its chances will be. The key to the fuel's success will be maintaining cost control over distribution.

With respect to a possible timeline for replacing 100LL, Minard said that there are conflicting estimates on when lead will be phased out. For this reason, his company's position is that it will wait for fuel standards to be set by ASTM and for industry to require a replacement before acting.

Richard Riley was then asked to comment on the logistical challenges to be faced when moving to an alternative fuel or a fuel that has a different octane rating. In reply, Riley said that it is important to understand that there is going to be a continuous state of change for quite some time and that there is not going to be an abrupt conversion to a different fuel. This is a situation which is going to cause problems.

For instance, his company is already looking at 82 octane unleaded Avgas (82UL) and it is clear that they are going to have to be very careful to ensure that they do not carry 82UL in a truck right after the truck has been used to deliver a load of 100LL, or the 82UL will be contaminated. Problems of this type will only get worse as the move is made away from petroleum based fuels. Once, we start to move away from totally petroleum based products (and 82UL will probably be a step in this direction since it will likely contain MTBE or ETBE) we will need to keep a careful watch, "so that we don't make a muck of things."

Fred Potter was then asked to comment, in the context of his experience with motor gasoline, on using different compounds (such as aromatics, or ethanol) to meet the octane needs of Avgas while at the same time meeting environmental goals. Fred responded by saying that in the motor gasoline market, it was the pressure from alternative fuels which had allowed the petroleum industry to develop the reformulated gasoline which is now cleaning up the air. And, while there are some

differences between the motor fuels market and the aviation market having to do with different price structures and certification and safety issues, he saw blended alternative liquid fuels becoming a contributor to a predominantly petroleum based reformulated aviation gasoline rather than being used as a neat replacement fuels.

Todd Sneller followed up by asking Fred what strategy should be followed during the transition so that the customers are not confused. Fred answered by saying that no one should underestimate how difficult the job will be. He pointed out that the petroleum companies have done such a good job, that, adjusted for inflation, it is cheaper to drive now than it has been at any time in the last 50 years. Therefore, he suggested that the question was how the alternative fuels can best work with the petroleum industry and that those people who were best at matching their message to the success of the existing industry would be most successful.

Continuing on this theme, Richard Riley was asked what he thought a fuel provider could do to inform its customer base about the coming fuels changes and about how they (the customers) should handle any technical differences of the fuels. Mr. Riley said that he did not think that it would be much of a problem, since the aviation community tends to be technically aware and the technical issues are not that bad.

Chuck Minard was asked if the fixed base operators (FBOs) would be the initial target for the transition or if it would result in others entering the customer base. His answer was that the FBO which owns its own fuels storage facilities was, and would remain, their primary customer. He also expressed concern about the fact that, at a time when the number of FBOs is already shrinking, the introduction of a new product will require FBOs to invest in additional storage capacity, which may drive more FBOs out of business.

Todd Sneller followed up on this question by asking Minard if he expected to see regional differences in the formulation of Avgas, similar to those seen with motor gasoline. The answer was no.

Jerrel Branson was then asked if the pattern of there being regional differences in the popularity of the alternative fuels used for automobiles (which is caused by there being different constituencies for fuels in different areas) will be mirrored with aviation fuels. His reply was that because aircraft travel large distances, there will have to be uniform fuel quality, distribution systems and refueling infrastructure throughout the country. He thought this will be a major factor for FBOs which will have to decide which fuels to support. He pointed out that this is a problem for natural gas which, despite the fact that it is both a good piston and a good turbine fuel, is constrained by the fact that it requires different fuel handling and storage methods than traditional liquid fuels.

On the follow up question, Branson was asked to give his opinion on whether piston and turbine powered aircraft would use the same fuels. His answer was that if they both used natural gas, yes. But, if agricultural based or blended fuels are chosen it was unlikely.

Todd Sneller then turned to Chuck Minard and asked him what challenges face the supplier of multiple fuels. Minard responded by pointing out that, for the refiner, 100LL is a specialty product which competes against the other products they refine and he expects the situation will be made even worse if the refiners have to make multiple products for the FBOs.

Going to Richard Riley, Sneller pointed out that in the motor gas market, refiners and retailers routinely deal with multiple fuels. So, he asked, what makes these two markets different? Riley said it was an issue of volume. Even premium gasoline, the smallest part of motor gasoline market, sells in much larger volumes than Avgas. Products produced in small volumes are handled differently at the refinery and in the distribution system, adding to their cost. As an extreme example, he said that the smallest production run for some products his company makes is

5 gallons. At that scale of production, the minimum cost for 5 gallons is \$85. And, even at that high a price, they are just paying for the paperwork and distribution costs and are making nothing on the product.

Going back to Fred Potter, Todd Sneller asked what types of incentives, if any, should be made available to fuel suppliers in order to facilitate the transition to alternative aviation fuels. Fred replied by saying that in the motor fuels market, it has made sense to subsidize ethanol and ETBE and that his first impression was that these same subsidies ought to apply to aviation fuel. He also said that the same logic ought to apply to natural gas refueling infrastructure for airplanes as for automobiles.

Following up on Fred's comments, Sneller asked Jerrel Branson where incentives should be applied, to the fuel or to the refueling infrastructure. Branson answered that the provisions of the Energy Policy Act of 1992, which gives tax credits for building alternative refueling facilities, should be expanded to cover off-road vehicles and aircraft. Branson added that a \$100,000 tax break should be sufficient in most cases. He also made the argument that the different alternative fuels should get more equal and fairer treatment, such as being taxed on a Btu basis.

Continuing on this subject, Chuck Minard was asked if he had an opinion as to where incentives could be most cost effectively applied. He answered that since aviation fuels are such a low volume product it would be very hard for a refiner to get a benefit from any incentive and so he had no idea as to where the incentive should go.

Changing the subject, Todd Sneller asked Richard Riley what Philips Petroleum is doing to evaluate or research alternative aviation fuels. Riley replied that while Phillips is working with Cessna and industry groups on issues such as 82UL, it is doing very little on its own. This is because it is very hard to convince management to do work which will benefit other companies. He pointed out that this is the reason for Industry groups which pool money and effort.

At this point Jerrel Branson was asked a question from the audience about the possibility of having dual-fuel airplanes in the same way that there are dual-fuel cars. He answered by saying there are obvious benefits to such a system since it allows more options for refueling.

MANUFACTURERS' RESPONSE TO ALTERNATIVE FUELS
PANEL

MONTY BARRETT
BARRETT PRODUCTION AIRCRAFT
SUMMARIZED COMMENTS

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Summary of Monty Barrett's Statement to
The Manufacturers' Response To Alternative Fuels Panel

Mr. Barrett reported that a few years ago, at the request of an airshow pilot, he began a series of tests to investigate the effects of increased compression ratios on engines to be used in the experimental category. The characteristics of these engines are that they use 6 lbs of air per horsepower/hour, they have brake specific fuel consumption 0.52 lbs of fuel per horsepower/hour on 100LL, they have a fuel/air ratio of 0.086 when they are leaned to best power, and they have 0.6 horsepower output per pound of engine weight.

The testing was done using a water brake with a high kinetic load. Data was collected by a computer capable of 1 millisecond sampling rates. And the PID (Proportional Integral Differential) speed controller was chosen to avoid the effects of inertia on the water brake.

Data was taken over a 10 year period, and all testing was done at the best power mixture. To date, this testing has shown that as the compression ratio is increased, EGT are lowered, and a point is reached, at 10.5:1, where there is no increase in EGTs even as the engine is leaned to the detonation threshold.

During this testing, detonation was detected by ear. Mr. Barrett was confident in his ability to detect detonation by this method, but expressed interest in the detonation detection system developed by Cessna.

According to Mr. Barrett, as the compression ratio is increased, the engine's performance improves. At the 10.5:1 ratio, with no other changes, the 260 hp, 380 lbs, Lycoming, 6 cylinder, IO-540 produces 300 hp. There is no increase in fuel consumption, but torsional vibrations do increase, and TBO is reduced. We have made some gains in those areas with lubricants and some modifications to the rotating systems and the assembly of crank cases.

He reported, as we approach the limits of useful exhaust gas temperature, we have begun to play with the effects of quench area. For those of you not familiar with quench area, it is a low volume area in the combustion chamber designed to accelerate the flame front for the rapid propagation of the fuel burn. We did this by welding areas up in the head, which is archaic, but it served the purpose. There are tremendous advances which can be made using quench areas. The manufacturers need to make a quantum leap into the 1950s here. They are behind on their research.

Also, we have discovered, using sophisticated cam programs, that there are errors in camshaft profile designs that contribute to premature retirement of some pretty expensive parts. One of the misconceptions that two major manufacturers labor under is that they have to have all this big high valve lift, and they don't. We found, using flow bench steady state technology, that air flow through the valve dramatically begins to reduce when the lift equals 0.2 times the diameter. Since then, we have made some improvements in that area with the valve seat used in the [Continental] IO-550 and now directly fitable on some of the engines in the IO-520s.

According to Mr. Barrett, the fuel servos used on fuel injected engines at the present time are of the mass airflow type using a fuel-air regulator section. There has been some development outside of the manufacturers with high gain ventures which are mechanical devices using improved aerodynamic shapes. The benefit is that the fuel regulators become a little more responsive to changes to mass air flow through fuel metering device.

Along with that, some of the auto manufacturers have developed fuel injection systems which have electronically controlled metering and timing of the fuel -- which would be a big improvement. These things all lead to rapid applicability to alternative fuels of one type or another, even possibly turbine fuel. I know Lycoming is playing with using a derivative of Jet A in a reciprocating engine. They claim that detonation can be controlled with no power loss by the proper injection of Jet A and a spark controlled ignition.

He said, there is an ignition system in test right now in field using a very superior device. It has a EPROM programmable advance curve. In other words, somebody takes the characteristics of the engine, writes a program into a chip, and the ignition system samples throttle angle, temperature, manifold pressure and adjusts the timing event to occur at the optimum time. It will vary from engine to engine. But, that program is under test even as we speak.

Mr. Barrett concluded by saying, "to summarize this, there are improvements that can be made to power to weight ratio using some of these advanced techniques that the automobile industry is now using, particularly the Japanese. They have kicked our posterior device with some of their cylinder head technology. Its workable on aircraft engines. Reliability can be enhanced to what today's TBO levels are. We have data now on 10:1 engines, that they are running in an aerobatic environment very near where the standard category engines are doing. We can take these engine enhancements and combine them with the ethanol, ETBE fuels and still keep the power to weight ratio down where it should be, and there is a good possibility to recover the power."

MANUFACTURERS' RESPONSE TO ALTERNATIVE FUELS

CESAR GONZALEZ
CESSNA AIRCRAFT COMPANY

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

CESSNA INDEPENDENT FUTURE FUELS FOR GENERAL AVIATION PROGRAM

- CESSNA COLLABORATES WITH INDUSTRY-WIDE EFFORTS, WHILE PURSUING AN INDEPENDENT FUELS DEVELOPMENT SUPPORT PROGRAM.
- THE CESSNA PROGRAM FOLLOWS GUIDELINES DEVELOPED DURING THE ASTM FUTURE FUELS FOR GENERAL AVIATION SYMPOSIUM HELD ON 29 JUNE 1988, IN BALTIMORE, MARYLAND.
 - REPRESENTATIVES FROM FUEL PRODUCERS, REGULATORY AGENCIES, USER ORGANIZATIONS, AND GENERAL AVIATION INDUSTRY, PARTICIPATED IN THAT EVENT.
 - IT WAS CONCLUDED THAT THE SHORT AND MID-TERM FUTURE OF GENERAL AVIATION WILL REMAIN HEAVILY DEPENDENT ON THE CONTINUED AVAILABILITY OF HIGH OCTANE AVIATION GASOLINES.
 - IT WAS FURTHER CONCLUDED THAT THE LONG TERM SURVIVAL OF THE PISTON FLEET, WILL DEPEND ON THE ABILITY OF THE GENERAL AVIATION INDUSTRY TO ADAPT ITS PISTON PRODUCTS TO USE FUELS AVAILABLE FROM LARGE POOLS, SUCH AS MOTOR GASOLINES AND TURBINE FUELS.

UNLEADED LOW OCTANE GRADE 82 UL AVIATION GASOLINES PHASE

- **EVENTS OF THE PAST SIX YEARS HAVE REINFORCED THE NEED FOR NEW GENERAL AVIATION AIRCRAFT CAPABLE OF USING READILY AVAILABLE BASE FUELS.**
 - **SERVICE EXPERIENCE HAS PROVEN THAT SUITABLE AVIATION GASOLINE CAN BE DERIVED FROM THE MOTOR GASOLINES POOL.**
 - **THE NEW 82 UL SPECIFICATION REPRESENTS A MAJOR ELEMENT OF THE OVERALL UNLEADED AVIATION GASOLINES PROGRAM.**
 - **MOTOR FUELS THAT ARE TO BE USED IN AIRCRAFT MUST BE SUBJECTED TO COMPLETE SCREENING QUALIFICATION TESTS, IN CONFORMANCE WITH GRADE 82 UL SPECIFICATION REQUIREMENTS.**
 - **THE 82 UL SPECIFICATION ADDRESSES THE QUALITY CONCERNS OF THE INDUSTRY, AND REPRESENTS A COST EFFECTIVE ALTERNATIVE FOR OPERATORS OF FUTURE GENERAL AVIATION AIRCRAFT.**
 - **THE 82 UL FUEL SIGNIFICANTLY EXPANDS THE NUMBER OF POTENTIAL SOURCES, TO IDEALLY MEET THE WIDESPREAD BUT LIMITED VOLUME DEMANDS OF THIS MARKET.**

GRADE 82 UL SPECIFICATION REQUIREMENTS

- THE 82 UL AVGAS SPECIFICATION ALLOWS THE USE OF ALIPHATIC ETHERS BUT LIMITS ALCOHOLS TO VERY LOW CONCENTRATIONS.
- FOLLOWING THE SUCCESSFUL COMPLETION OF SCREENING TESTS, THE SELECTED FUEL BATCH IS BLENDED WITH PURPLE COLORANT DYES FOR IDENTIFICATION.
- FUEL CERTIFICATION REPORTS MUST BE COMPLETE SHOWING COMPLIANCE WITH APPLICABLE SCREENING TESTS AND COLOR IDENTIFICATION REQUIREMENTS - PROOF OF COMPLIANCE IS ESSENTIAL.
- THE RESULT IS FIRST AND FOREMOST AN AVIATION FUEL.

ASTM GRADE 82 UL AVGAS SPECIFICATION

- SPECIFICATION WAS DRAFTED BY ASTM TASK GROUP ORGANIZED FOR THAT PURPOSE DURING MEETINGS HELD IN DECEMBER 1989.
 - FIRST DRAFT COMPLETED IN SEPTEMBER 1992.
 - THE SOUTHWEST RESEARCH INSTITUTE, FAA, PHILLIPS PETROLEUM, AND CESSNA COLLABORATED WITH THE ASTM TASK GROUP TO ESTABLISH GRADE 82 UL SPECIFICATION REQUIREMENTS.
 - DOCUMENT HAS EXPERIENCED EIGHT REFINEMENT CYCLES TO REFLECT INPUTS EXTENDED BY ASTM MEMBERS REPRESENTING A WIDE RANGE OF DISCIPLINES AND INTERESTS.
 - GRADE 82 UL AVGAS SPECIFICATION BASED ON MOTOR GASOLINES IS CURRENTLY UNDER THE ASTM APPROVAL BALLOTING PROCESS.
 - THE DOCUMENT REPRESENTS A SAFE, PRACTICAL, AND LOGICAL INITIATIVE IN SUPPORT OF A BETTER FUTURE FOR THE GENERAL AVIATION INDUSTRY.

COOPERATIVE UNLEADED HIGH OCTANE AVIATION GASOLINES PROGRAM

- **COOPERATIVE EFFORTS RELATED TO THE DEVELOPMENT OF UNLEADED HIGH OCTANE AVIATION GASOLINES ARE SHIFTING FROM ASTM TO CRC.**
 - **CRC ACTIVITIES HAVE BEEN SEGREGATED INTO TWO DISTINCT GROUPS, ONE DEALING WITH AIRCRAFT ENGINE OCTANE RATING ISSUES, WHILE THE OTHER COVERS A VARIETY OF FUEL CHARACTERISTICS SUCH AS FREEZE POINT AND VOLATILITY.**
 - **CRC GROUPS HELD MEETINGS ON 21 JUNE 1995 IN INDIANAPOLIS AND 19 SEPTEMBER 1995 IN OSHKOSH. NEXT MEETING IS SCHEDULED FOR DECEMBER 1995 IN HOUSTON.**

CESSNA UNLEADED HIGH OCTANE AVIATION GASOLINES PROGRAM

- **CESSNA COLLABORATES WITH INDUSTRY-WIDE EFFORTS, WHILE PURSUING AN INDEPENDENT HIGH OCTANE FUELS DEVELOPMENT SUPPORT PROGRAM.**
 - **CESSNA FEELS A STRONG INCENTIVE TO PURSUE THIS PROGRAM, SINCE CESSNA AIRPLANES IN SERVICE COMPRISE ALMOST HALF OF THE ENTIRE GENERAL AVIATION PISTON FLEET AROUND THE WORLD.**
 - **INITIAL PHASE OF CESSNA PROGRAM DEDICATED TO DEVELOP TEST EQUIPMENT, PROCEDURES AND REFERENCE FUELS REQUIRED TO EVALUATE FUTURE UNLEADED CANDIDATE FUELS, IS NEARING COMPLETION.**
 - **EVALUATION OF CANDIDATE UNLEADED FUELS WILL BE INITIALLY TARGETED TO ESTABLISH IMPACT OF NEW PROPOSED FUELS ON IN-SERVICE AIRCRAFT.**
 - **WITH FIELD OF CANDIDATE FUELS NARROWED TO JUST ONE OR TWO FUELS, FINAL EVALUATIONS MUST BE PERFORMED ON CLEAN NEW OR REMANUFACTURED ENGINES.**
 - **CESSNA PROPOSES THE PARTITIONING OF THE FLEET INTO GENERIC GROUPS, AND TO CERTIFY NEW FUELS USAGE ON REPRESENTATIVE SPECIMENS OF EACH GROUP. IT IS NO LONGER POSSIBLE TO ADDRESS CERTIFICATION ISSUES ON AN INDIVIDUAL AIRFRAME/ENGINE BASIS.**

ESSENTIAL ELEMENTS OF THE CESSNA FUTURE FUELS PROGRAM

INSTRUMENTATION AND EQUIPMENT

- **CESSNA DETONATION INDICATION SYSTEM (CEDI)**
 - **CEDI SYSTEM DEVELOPMENT HAS BEEN COMPLETED AND PRODUCTION UNITS ARE COMMERCIALY AVAILABLE THROUGH THE PCB PIEZOTRONICS ORGANIZATION IN DEPEW, NEW YORK.**
 - **A PATENT APPLICATION HAS BEEN FILED, AND A ROYALTY FREE LICENSE HAS BEEN EXTENDED BY CESSNA TO PCB.**
 - **SYSTEM SPECIFICALLY DEVELOPED FOR LABORATORY AND ON-BOARD AIRCRAFT INSTALLATIONS.**
 - **NO EQUIPMENT MALFUNCTIONS HAVE BEEN EXPERIENCED TO DATE DURING EXTENSIVE GROUND AND FLIGHT TESTING, WITH THREE CEDI SYSTEMS.**
 - **CESSNA IS SEEKING FAA APPROVAL FOR CEDI SYSTEMS AND ASSOCIATED TEST METHODS, AS AN ALTERNATE TO CURRENT FAA ADVISORY CIRCULAR NO. 33.47 FOR CERTIFICATION OF AIRFRAMES AND ENGINES.**

ESSENTIAL ELEMENTS OF THE CESSNA FUTURE FUELS PROGRAM

- **CESSNA FUELS BLENDER SYSTEM.**

- **DEVELOPMENT OF THE FUELS BLENDER SYSTEM HAS BEEN COMPLETED AND U.S. PATENT GRANTED.**
- **SYSTEM PROVIDES MEANS OF PRECISE IN-LINE BLENDING OF TWO REFERENCE FUELS UNDER LABORATORY OR ON-BOARD CONDITIONS.**
- **DISPLAYS TOTAL, PARTIAL, AND BLENDING RATIOS DATA.**
- **WITH OPTIONAL PC LINK AND APPROPRIATE CALIBRATION BLENDING DATA, THE SYSTEM PROVIDES INSTANTANEOUS OCTANE RATINGS OF FUELS SUPPLIED TO TEST ENGINES.**

- **CESSNA SYSTEMS INTEGRATION**

- **CONCURRENT ADOPTION OF DETONATION CEDI AND FUELS BLENDER SYSTEMS ALLOWS PRECISE AND REPEATABLE TESTS RESULTS, AND COMBUSTION KNOCK INTENSITY NUMBERS MAY BE RECORDED WITH CORRESPONDING FUEL OCTANE RATINGS AND OTHER ENGINE AND AMBIENT PARAMETERS.**

ESSENTIAL ELEMENTS OF THE CESSNA FUTURE FUELS PROGRAM

- **REFERENCE FUELS**

- **ON TESTS RELATED TO GRADE 82 UL FUELS CESSNA HAS ADOPTED THREE DISTINCT 82 UL TEST FUELS BLENDED BY PHILLIPS, AND CERTIFIED CRC RMFD REFERENCE FUELS.**
- **ON TESTS RELATED TO HIGH OCTANE UNLEADED FUELS CESSNA HAS ADOPTED ASTM PRIMARY FUELS, ASTM 100/130 AVGAS CHECK FUEL, AND A SPECIAL LL100 AVGAS WITH REDUCED RICH RATING.**
- **TESTS WILL BE INITIATED DURING DECEMBER 1995 WITH A LIGHT ALKYLATION NAPHTHA PROVIDED BY THE BRITISH PETROLEUM COMPANY. PRODUCT MAY BE ADOPTED AS REFERENCE FUEL DURING EVALUATIONS OF CANDIDATE UNLEADED BLENDS.**

CESSNA FUTURE FUELS PROGRAM TEST EQUIPMENT

- **GROUND ENGINE TEST STAND**
 - EQUIPPED WITH TCM TSIO-520 TURBOCHARGED, SIX CYLINDER 300 HP ENGINE.
 - SPECIALLY INSTRUMENTED AND INTERFACED WITH DATA ACQUISITION SYSTEMS TO SUPPORT FUEL TESTS.
 - REPRESENTATIVE OF ON-BOARD AIRCRAFT INSTALLATIONS, AND PROVIDED WITH INDUCTION AIR HEATING.
- **FUEL SYSTEMS DEVELOPMENT GROUND TEST AIRFRAME.**
 - MODEL 172 SERIES FUSELAGE WITH A LYCOMING IO-360 ENGINE HAS BEEN EQUIPPED WITH SPECIAL FUEL TANKS AND ACCESSORIES, TO CONTROL FUEL TEMPERATURES AND SIMULATE ALTITUDE CONDITIONS.
 - TO DEVELOP STATE OF THE ART AIRFRAME FUEL SYSTEMS, AND UPGRADE ENGINE FUEL SYSTEMS TO ADOPT NEW LOW OCTANE FUELS BASED ON MOTOR GASOLINES.
 - ASSESSMENT OF ALTERNATE FUELS IMPACT ON ENGINE PERFORMANCE AND CONSUMPTION RATES.

- **FUTURE FUELS TEST AIRCRAFT**

- **CESSNA MODEL 303 TWIN ENGINE AIRCRAFT WITH TCM TSIO 520 TURBOCHARGED ENGINES.**
- **AIRFRAME FUEL STORAGE AND MANAGEMENT SYSTEM MODIFIED TO SELECTIVELY FEED THE RIGHT ENGINE WITH UP TO FIVE DISTINCT FUELS.**
- **AIRCRAFT EQUIPPED TO ADAPT CESSNA CEDI DETONATION AND FUELS BLENDER SYSTEMS, AND COMPLETE DATA ACQUISITION PROVISIONS.**

AUTOMOTIVE EXPERIENCE WITH ALCOHOL FUELS IN BRAZIL

- DURING THE 1970'S, THE GOVERNMENT IN BRAZIL IMPLEMENTED A PROGRAM AIMED AT THE DEVELOPMENT OF AUTOMOTIVE AND AVIATION ENGINES AND RELATED SYSTEMS CAPABLE OF BURNING ALCOHOLS.
 - UNDER STRONG FUEL AND VEHICLE GOVERNMENT INCENTIVES, THE AUTOMOBILE MANUFACTURERS PRODUCED BOTH GASOLINE AND ALCOHOL FUELED CARS DURING THE 80'S. BY 1986, 95% OF AUTOMOBILES SOLD WERE ALCOHOL FUELED.
 - GOVERNMENT FUEL AND VEHICLE INCENTIVES WERE GRADUALLY REDUCED AFTER THE MID 80'S, AND THE DEMAND FOR ALCOHOL FUELED AUTOMOBILES DECLINED. THE VAST MAJORITY OF AUTOMOBILES PRODUCED IN BRAZIL TODAY ARE FUELED WITH GASOLINE/ALCOHOL BLENDS.
 - STARTING AND ENGINE STOPPAGE PROBLEMS AT AMBIENT TEMPERATURES BELOW 50°F, CORROSION OF EXHAUST AND FUEL SYSTEM COMPONENTS AND HIGHER CONSUMPTION RATES, CONTINUE TO AFFECT THE ALCOHOL FUELED AUTOMOTIVE FLEET.
 - WHILE PROPONENTS OF ALCOHOL FUELS CONTINUE TO EXHORT THE MERITS OF ALCOHOL FUELS, NO MENTION IS MADE OF THE ADVERSE IMPACT THAT GOVERNMENT SUBSIDIES HAD ON THE OVERALL BRAZILIAN ECONOMY.
 - LIKEWISE, NO MENTION IS MADE OF THE IMPACT THAT BIOFUELS HAD ON THE ENVIRONMENT AND RESOURCES, CAUSED BY RAZING OF FORESTS TO CLEAR LANDS INCAPABLE OF SUPPORTING CROPS FOR MORE THAN TWO OR THREE YEARS.

AVIATION EXPERIENCE WITH ALCOHOL FUELS IN BRAZIL

- CONTACTS WITH THE CTA (AERONAUTICAL TECHNICAL CENTER) IN BRAZIL, WERE ESTABLISHED TO SEEK INFORMATION ON AVIATION USE OF ALCOHOL FUELS.
 - THROUGH THE CTA BRANCH OF THE BRAZILIAN AIR FORCE, THE GOVERNMENT PURSUED A PARALLEL AVIATION ALCOHOL FUELS PROGRAM.
 - MOST OF THE DEVELOPMENT WORK INVOLVED LYCOMING ENGINES OPERATED ON GROUND DYNAMOMETER SETTINGS.
 - TWO OR THREE AIRCRAFT INSTALLATIONS WERE TESTED WITH MIXED RESULTS. PROBLEMS GENERALLY DEVELOPED WHEN THE AIRCRAFT REMAINED INACTIVE FOR SEVERAL WEEKS.
 - THE PROGRAM WAS ABANDONED DUE TO LACK OF MARKET INTEREST, WITHOUT A SINGLE AIRCRAFT/ENGINE CERTIFICATION.

OUTLOOK ON FUTURE FUELS FOR GENERAL AVIATION

- CESSNA WILL CONTINUE TO COLLABORATE WITH INDUSTRY-WIDE EFFORTS TO DEVELOP UNLEADED LOW OCTANE AND HIGH OCTANE AVIATION GASOLINES.
- CESSNA WILL CONTINUE TO PURSUE THE INDEPENDENT FUELS DEVELOPMENT SUPPORT PROGRAM, FOLLOWING THE GUIDELINES ESTABLISHED BY THE ASTM FUTURE FUELS FOR GENERAL AVIATION SYMPOSIUM HELD IN JUNE 1988, IN BALTIMORE.
 - FUTURE PISTON PRODUCTS MUST OPERATE WITH FUELS AVAILABLE FROM LARGE POOLS, SUCH AS MOTORGASOLINES AND TURBINE FUELS.
 - APPROVAL OF THE GRADE 82 UL ASTM SPECIFICATION IS ESSENTIAL TO THE CERTIFICATION OF NEW AIRCRAFT CAPABLE OF OPERATION ON FUELS BASED ON MOTORGASOLINES.
 - THE NEW GRADE 82 UL AVGAS IS PRIMARILY INTENDED FOR NEW PISTON AIRCRAFT SPECIFICALLY DESIGNED FOR THAT PURPOSE, AND REPRESENTS A SAFETY NET FOR AIRCRAFT CERTIFIED FOR GRADE 80/87 AVGAS, THAT REPRESENT APPROXIMATELY 60% OF THE CURRENT U.S. FLEET.
 - THE DEVELOPMENT OF UNLEADED HIGH OCTANE AVGAS IS CRUCIAL TO THE SURVIVAL OF THE CURRENT PISTON FLEET STRICTLY DEPENDENT ON GRADE LL100 AND 100/130 FUELS.
 - THE UNLEADED HIGH OCTANE FUELS MUST OFFER THE HIGHEST OCTANE RATINGS ATTAINABLE AT PUMP COSTS COMPARABLE TO CURRENT PRICES. REDUCED OCTANE RATINGS MAY REQUIRE POWERPLANT MODIFICATIONS AND/OR OPERATIONAL RESTRICTIONS ON SOME AIRCRAFT TYPES.

OUTLOOK ON FUTURE FUELS FOR GENERAL AVIATION

- **CESSNA SUPPORTS THE DEVELOPMENT OF PETROLEUM BASED UNLEADED LOW AND HIGH OCTANE GASOLINES, BLENDED WITH ETHERS BUT WITH ALCOHOLS LIMITED TO VERY LOW CONCENTRATIONS.**
 - **OUTLOOK DERIVED FROM POSITIVE SERVICE AND TEST EXPERIENCE WITH PETROLEUM BASED FUELS, AND TO A LIMITED DEGREE WITH ETHERS.**
 - **ADVERSE SERVICE AND TEST EXPERIENCE WITH ALCOHOLS AS FUEL BLENDING COMPONENTS AND AS DE-ICING FLUIDS, REVEALS INCREASED MAINTENANCE AND SERVICE BURDENS, AND A NEGATIVE IMPACT ON OPERATIONAL COSTS AND SAFETY.**
 - **COMBINED ECONOMIC, ENVIRONMENTAL, OPERATIONAL AND LOGISTIC CONSIDERATIONS, STRONGLY SUGGEST THAT ALTERNATIVES TO WELL PROVEN AVIATION FUELS, SHOULD CONTINUE TO BE BASED ON PETROLEUM COMPONENTS, WHILE USE OF OXYGENATE BLENDS SHOULD BE LIMITED TO ALIPHATIC ETHERS.**

OUTLOOK ON FUTURE FUELS FOR GENERAL AVIATION

- WHILE ALCOHOLS MAY PROVE TO BE THE IDEAL GENERAL AVIATION FUELS FOR THE LONG RANGE FUTURE, IN THE NEAR AND MID TERM FUTURE IT IS IMPRACTICAL TO SWITCH THE CURRENT FLEET OR DEVELOP NEW PRODUCTS USING SUCH FUELS.
 - IT IS WELL RECOGNIZED THAT DISTRIBUTION LOGISTICS REPRESENT THE HIGHEST CONTRIBUTIONS TO CURRENT AVIATION GASOLINES PUMP PRICES, DUE TO THE LIMITED OVERALL VOLUME OF THIS MARKET AND THEIR WIDESPREAD USE.
 - IN THE U.S. ALONE, EIGHT AVGAS PRODUCTION SOURCES MUST SERVE SOME 17,000 AIRPORTS. THIS IS THE MAIN REASON FOR CESSNA'S COMMITMENT TO PISTON ENGINE FUELS TAPPED FROM LARGE POOLS SHARED WITH OTHER TRANSPORTATION SECTORS.
 - ADOPTION OF ALCOHOLS ON GENERAL AVIATION AIRCRAFT SHOULD BE CONSIDERED ONLY WHEN ON A WORLD WIDE BASIS THE MAJORITY OF AIRLINERS, MILITARY AIRCRAFT, AND ROAD VEHICLES USE ALCOHOLS.
 - GENERAL AVIATION AIRCRAFT PRODUCED IN THE UNITED STATES MUST CONTINUE TO BE CAPABLE OF OPERATION WITH FUELS READILY AVAILABLE AROUND THE GLOBE.
 - GENERAL AVIATION AIRPLANES MUST CONTINUE TO BE SERVICED WITH FUELS OF UNIFORM CHARACTERISTICS. SWITCH LOADING OF ALCOHOLS AND GASOLINES COMPROMISES SAFETY.

OUTLOOK ON FUTURE FUELS FOR GENERAL AVIATION (CONTINUED)

- PHASEOUT OF LEAD ADDITIVES MUST REMAIN LINKED TO CURRENT INDUSTRY EFFORTS TO DEVELOP LOW AND HIGH OCTANE UNLEADED AVIATION GASOLINES AND ETHER BLENDS.**
- A DECISION TO PHASE OUT LEAD ADDITIVES BASED SOLELY ON A TRANSITION TO ALTERNATIVE ALCOHOL FUELS IS PREMATURE. SIMPLY STATED, THE TIMING IS WRONG.**

LUNCHEON ADDRESS

GARRY MAURO
COMMISSIONER
TEXAS GENERAL LAND OFFICE
SUMMARIZED COMMENTS

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Garry Mauro
Commissioner
Texas General Land Office
Luncheon Address

Garry Mauro started out by describing the duties of the Texas Land Commissioner and how he is responsible for managing 20 million acres of public land, including 18,000 producing oil wells, the revenue from which goes to the Permanent University Fund.

Mauro then explained that he had become involved in alternative fuels because, when he was elected Land Commissioner in 1982 the price of oil was \$34 a barrel. When it dropped to \$9 a barrel he had to find some way to improve the state's revenues. He decided that the best way to do this was to increase the use and price of natural gas so as to compensate for the decrease in price of oil.

Mauro said that his message was simple.

When you look at the economy of the United States of America, when you look at our economic productivity, when you look at the environmental problems we have [as a result of] maintaining our economic viability, then you quickly realize that there are many niche markets for fuels other than gasoline and diesel. If you want to make the economy more viable, then you better stop thinking of the fuels markets as homogeneous and you better start thinking of them as heterogeneous. And, when you look at ethanol and methanol and fuel cells and natural gas and propane you quickly come to the conclusion that you need to improve the sales of all of these fuels.

He noted that when he goes to alternative fuels conferences, the supporters of the different alternative fuels are always fighting among themselves, and he said that this has got to stop. He argued that the alternative fuels aren't in competition with each other, but rather that they needed to work on taking market share away from gas and diesel and stop the fighting among themselves. He said that his personal opinion was that there are plenty of niche markets for all the fuels, "if we let the marketplace and the entrepreneurs prove up those niche markets."

He then stated that there is a law in Texas that bus fleets must convert to alternative fuels by 1998. So, Texas is taking alternative fuels seriously. They may be proponents of natural gas, but along the way they have come to the belief that all alternative fuels make sense in the Texas Economy. As further proof of the seriousness with which Texas takes alternative fuels, he gave a description of the Alternative Fuels Council, of which he is member, and how it has \$50 million of bonding authority and \$6 million of grants and is pushing alternative fuels projects in the state.

Mauro then addressed the economic reasons for supporting alternative fuels, stating, "We can't spend \$50 billion a year and growing importing oil and stay competitive. I don't believe that we are going to become energy independent. But, I do believe a little here with methanol, a little there with ethanol, a little here with compressed natural gas, a little there with LNG, a little here with propane, as we develop those new markets, we can at least keep that figure constant so our economy will grow and that \$50 billion will be a small figure as compared to the gross national product. I think that ought to be a goal for all of us." "For pure economics, all of us ought to be supportive of alternative fuels. It creates jobs in our great country."

He also talked about the part alternative fuels can play in cleaning up the environment. "The fact is, in this part of Texas, the vast majority of our air pollution problems are tied to one thing and one thing only, the transportation sector. Now the aviation transportation is a very small segment of that, but it's still part of the same problem. And, the fact is if we do not go beyond reformulated gasoline and reformulated diesel, we will not clean up the air and make it safe to breathe in Texas for the next 20 years. We will have marginal improvements till the year 2002, and then the growth

gets so overwhelming that we go back to having horrible days again. That's just what the mathematical models will tell you. And what experience is telling us, is that we are experiencing much worse days in our great state well ahead of what the mathematical models call for."

Recognizing that it was not possible to take all the gasoline and diesel powered vehicles off the roads, he said, "We need to find a way to make high mileage vehicles that regularly and routinely spend lots of hours on the road in high population areas burn something especially clean." He noted that it particularly made sense to convert to these fuels because these fuels are cheaper and more economical than the fuels they would replace.

He also said that, because of the benefits to the economy, jobs and the environment, there is a need to develop short term, mid term and long term strategies to promote these fuels. He said the most important reason for doing this was to clean up the air, again noting that the number of vehicle miles traveled is growing so quickly that it is more than compensating for cleaner vehicles, gasoline and diesel and that what is needed is a super clean fuel.

He talked about advances being made in fuel cell technology and described a fuel cell bus that he had recently seen which only produces water as waste product, stating that this was an example of alternative fuels technology at its finest.

He called on the conference attendees to remember the big picture and to develop aggressive strategies to promote alternative fuels. He said, "I'm really interested in watching what you all do with aviation fuels. What I know about alternative fuels, its going to be an interesting niche market. There are some real opportunities for real entrepreneurs in this area."

He was then asked by someone in the audience, Who is going to lead the way? To this question he answered, "I don't expect the oil companies to lead the way." "My prediction is that you're going to see some entrepreneurs apply technology, develop niche markets, and then you're going to see the oil companies get involved." "You have mostly refiners running domestic major oil companies in the United States. And the reason is that's where the profits are coming from. Therefore, its going to be very difficult for a corporate leadership that's making its profits off gasoline and diesel and who came up through the company learning how to refine gasoline and diesel to decide that they are going to make their future in something other than gasoline or diesel. But having said that, from the same historical perspective, every time entrepreneurs have developed niche markets the oil companies have always come in and bought those entrepreneurs out and then applied that entrepreneur on the technology in a big way and make it work. I suspect we are still in the stage where the small entrepreneur will have to develop the niche market first."

Russel Smith, of the Texas Renewable Energy Industries Association, (TREIA) then asked, "What are the chances of getting a couple of renewable fuels folks on the Alternative Fuels Council?" Mauro replied, "It was created by legislation, so all we'd have to do is get another legislator to agree to do it. Put a renewable fuels person on it, and I would be more than happy to support that. I am all for it. I view the alternative fuels council as a good way to put some low cost financing money in to some high risk project, or at least projects that ... See the way that we view our money is to try to finance cost effective alternative fuels projects. And, having said that, I don't think that financing is a big problem right now. We'll be glad to get you all on the council."

Jill Hamilton, of IRI, asked for strategic advice on how to advance alternative fuels in aviation. Gary Mauro said, first of all develop common goals and define what you want to do. He said that he had defined what he wanted to do as reducing the impact of imported oil on the national economy, creating jobs, and solving an environmental problem and said that, once he had defined these three goals, then he was able to move the ball forward. He noted that all too often, when he goes to a conference the participants have no idea what they are there for and many of them don't

think there is a problem. So, he said there is a need to figure out what the common problems are and to develop common goals.

Mauro closed by praising President Clinton and Vice President Gore for their understanding of alternative fuels issues. He said that they do understand the issue, they do believe that we have to move away from the homogeneous fuel model and that what they really want from us is a blueprint on how to use alternative fuels to improve the environment and strengthen the economy.

**RENEWABLE AVIATION FUELS DEVELOPMENT CENTER
(RAFDC)**

**MAX SHAUCK
CHAIRMAN & DIRECTOR OF AVIATION SCIENCES
BAYLOR UNIVERSITY**

**FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY**

A Program To Advance The Use Of Ethanol As An Aviation Fuel

Executive Summary

By the end of this year, the Renewable Aviation Fuels Development Center (RAFDC) at Baylor University expects to gain the first Federal Aviation Administration (FAA) certification of an aircraft engine and airframe combination to run on ethanol. Therefore, RAFDC proposes a program to advance the use of ethanol as an aviation fuel. As part of this program, agricultural aviation businesses and flight schools, which own centralized fleets will be the focus of initial efforts to convert single aircraft and fleets to run on ethanol.

In addition, RAFDC has been approached by a number of state aviation departments who have inquired about the possibility of converting state-owned aircraft to run on ethanol. Under this program, RAFDC would work with these state aviation departments to convert their aircraft.

After almost fifteen years of research, testing and demonstrations, it is time to introduce ethanol into the piston-powered general-aviation fleet. Because of a number of circumstances, a replacement for low lead, high octane aviation fuel (Avgas) is urgently needed. Ethanol is the best fuel to meet this need and is closest to full commercialization.

The parts needed to modify an aircraft are either off-the-shelf components or can be readily fabricated. The technology has proven to be commercially viable. If, as is expected, leaded-Avgas is phased-out in the next few years, aircraft that cannot use low octane fuel will be a significant market for ethanol. No other high octane replacement fuel has been identified. Such aircraft use approximately half of the Avgas sold in this country.

Barriers to entering the market are: 1) Obtaining the resources needed, both in terms of personnel and money, to complete FAA certification testing for as many aircraft as possible; 2) Lack of public knowledge about ethanol as an aviation fuel (this includes demonstrating the economic viability of the fuel); and 3) The need to establish an ethanol distribution network for airports.

RAFDC is certifying engines and airframes on ethanol and is working to educate the public and the general aviation community about ethanol's benefits. The point has been reached where there is now a need to work with the fuel providers/distributors, fixed base operators (FBOs), Ag aviators, flight schools, and state aviation officials to develop an ethanol distribution network.

Section 1. Program Description

RAFDC proposes to coordinate a joint program involving the Governors' Ethanol Coalition, (GEC) state agriculture and energy offices, the U.S. Department of Energy, state aviation departments, represented by the National Association of State Aviation Officials, the U.S. Department of Agriculture, FAA, state corn growers associations, the National Corn Growers Association, and the ethanol industry. As part of this program, FBOs and other organizations, such as Ag aviators, flight schools, which own centralized fleets will be targeted to convert to ethanol. Later, ethanol fueling stations will be placed in selected airports -- with emphasis on those states that are part of the Governors' Ethanol Coalition.

In addition, another goal of this program will be to work with interested state aviation departments to convert state-owned aircraft to run on ethanol. Ultimately, it would be the goal of this program to convert state-owned aircraft in each GEC state to operate on ethanol.

In implementing the first portion of this program, RAFDC will hold a series of regional meetings so as to form a strong private sector alliance between ethanol producers/distributors, fuel distributors and FBOs to carry out the logistical operations needed to provide ethanol to the aviation market. In addition, RAFDC will coordinate this effort with work being done to establish automotive ethanol fueling stations through out the Midwest.

The successful completion of this project will not be possible without the support of all the organizations listed above. As has been proven with the attempts to implement ethanol in the automotive market, it is not easy to overcome the advantage that existing infrastructure and governmental regulations give to established fuels. Fortunately, as is described below, ethanol has a number of technical and economic characteristics, which make it especially suited for use as an aviation fuel. **This program must be designed to make the aviation community aware of those characteristics and to ensure that they are fully able to take advantage of them.**

In an era in which there is little, if any, political support for government programs that interfere with the market place or which are seen to benefit one industry, the coalition that develops to support this implementation program must work to ensure that, at the very least, government impediments to its success are removed. This means that we must work with regulatory agencies at all levels to see that uniform laws and standards are adopted for the use of ethanol as an aviation fuel.

Section 2. Background

The Clean Air Act mandates the phased removal of all lead from gasoline. The General Aviation Manufacturers Association recommends a minimum motor octane of 98 for Avgas. But, so far, there has been an inability to commercially produce Avgas with a motor octane rating of 98 without the use of metallic additives. Because of this, the Environmental Protection Agency (EPA) has allowed Avgas to continue to contain lead. However, it is expected that EPA will move to phase out the lead in Avgas over the next several years. If this happens, it will cause a problem for the General Aviation community unless a solution is in place.

Fortunately, ethanol can be economically used as an aviation fuel. It exceeds the minimum octane requirement, and needed modifications to an aircraft to permit its use are minor. With both carbureted and fuel injected engines, the only adjustments need are to ensure adequate fuel flow. In the case of the carburetor, the fuel jets are replaced with larger sized jets. In the case of the fuel injection system the lower idle valves and the mixture control valves are replaced, and injector nozzles with larger orifices are installed.

Potential cold start problems have been solved in a manner similar to the one implemented by the Brazilians for their ethanol powered automobiles. A one gallon auxiliary tank with gasoline is used to prime engines in cold weather. While this system is simple and works very well, it does involve the use of a second fuel. Therefore, testing of denaturants which increase the Reid vapor pressure (Rvp) of the fuel sufficiently to eliminate the cold start problem is underway.

The only materials compatibility problem encountered involves a reaction between ethanol and aluminum in fuel lines and fuel tanks. The solution to this problem adopted in the past is the allodization of all fuel wetted aluminum components. However, in the last few years ethanol producers have added an anti-oxidant to ethanol to avoid reaction between floating aluminum fuel tops and ethanol in storage tanks. This additive eliminates the need for allodizing aluminum components in aircraft.

Before any modification can be made to an aircraft engaged in civil commercial operations, a Supplemental Type Certificate (STC) for that modification must be obtained from the FAA. In the case of a new fuel, such as ethanol, both the engine and the airframe must undergo FAA testing. STCs for ethanol have already been obtained for the Lycoming IO-540 & O-235 series of engines. And, work is currently underway to obtain airframe certification for two aircraft, the Cessna 152 and the Piper Pawnee.

As part of the FAA certification testing, the engine is disassembled and all parts subject to wear are measured. The engine is then reassembled and tested for power development and detonation resistance. At this point an 150 hour endurance test is run according to a specified schedule of high power settings and engine temperatures. During the test the following parameters are monitored:

1. Power output.
2. Specific fuel consumption (at various loads).
3. Engine operating temperatures - cylinder head temperatures, exhaust gas temperatures, and oil temperatures.
4. Detonation resistance characteristics.
5. Exhaust emissions.

At the conclusion of the endurance test, the engine is disassembled and again measured to determine the amount of wear experienced. In these tests, ethanol has developed much more

than rated power (which is established using Avgas), resisted detonation much better than Avgas, runs considerably cooler, and experienced less wear than on Avgas.

In addition, testing at the Southwest Research Institute has shown that ethanol meets or exceeds all requirements for lubricity, flame luminosity, and compatibility with the elastomers found in airplane engines.

Section 3. Ethanol's Advantages

Ethanol has a number advantages when compared to Avgas. Its ignition characteristics are superior to Avgas. Because it has a wide range of flammability (burns well under different temperatures and pressures), ethanol ignites smoothly and develops a stable flame front. It also has superior resistance to premature ignition or knocking. This is in comparison with Avgas which is estimated to ignite inappropriately (out of sequence) as much of 20% of the time.

Knocking can greatly reduce the life of an engine, and can, in extreme cases, lead to sudden engine failure. Because ethanol greatly resists knocking, its use will reduce the stress on the engine, extending its life and improving its safety.

Ethanol has a lower vapor pressure than Avgas. Its Rvp is approximately 2.5 psi versus 5.5-7.5 psi for Avgas. While this characteristic can cause difficulties in starting the engine in cold weather, it provides an important safety advantage because it reduces the chance of vapor locking the fuel system. Vapor lock in an aircraft is most likely to occur during takeoff because of high engine temperatures. This is the most dangerous time for an aircraft to lose power. The low Rvp also means that there will be less evaporative emissions of volatile organic compounds (VOCs) from aircraft fuel systems when they are sitting on the ground. VOCs are one of the major precursors for smog. (Evaporative emissions also occur when the plane is being used, but are less of a problem as most aircraft operations take place at altitudes where VOC emissions do not affect ground level air quality.)

Ethanol burns at a lower temperature than Avgas, even while it produces more power. As a result, engines run cooler and are subject to less stress. This further increases the life of the engine. It also makes it possible to further reduce emissions of VOCs while operating in the mixing layer -- the part of the atmosphere which affects ground level air quality. Because of the high power demands of takeoff, the engine is run very rich -- using unburned fuel to cool the engine. When operating on ethanol, it is not necessary to do this and consequently, that portion of the flight which most affects ground level air quality is less polluting. (An important phenomenon.)

Ethanol also burns more cleanly than Avgas. Build up of combustion deposits in the engine is greatly reduced, as is contamination of engine oil. Based on the above characteristics, and the fact that ethanol has better lubricity than Avgas, the FAA Designated Engineering Representative who observed the certification testing estimated that the time between overhaul (TBO) can be safely doubled for engines using ethanol. If engine testing and flight operations confirms this appraisal, it will significantly reduce the cost of operating aircraft on ethanol.

Section 4. Energy Impact

Adoption of this technology by a large percentage of the piston powered aircraft fleet will have significant energy impacts. It is estimated that there are 163,000 aircraft in general aviation, using around 300 million gallons of fuel per year.

By providing a new, large (in terms of existing markets) market for ethanol, the ethanol industry will be strengthened and the energy diversity of the country will be increased. This will further a number of national policies.

In January, 1994, President Clinton said, "My administration is committed to encouraging the production and use of domestically produced renewable fuels. If our nation is to have a secure, environmentally sound energy supply, we must sustain a diverse domestic energy industry."

In the Energy Policy Act of 1992, Congress recognized the dangers of the nation's growing dependence on imported petroleum and mandated a number of actions to reduce petroleum usage. Transitioning to ethanol will further these goals by reducing the nation's usage of fossil fuels and dependence on imported petroleum. According to the most recent studies by the U.S. Department of Agriculture's Office of Energy and the Institute for Local Self Reliance, the average energy balance for the ethanol industry is 1.3:1. 1.3 times more energy is produced in the form of ethanol than is used in growing and converting feedstocks into ethanol. This ratio is improving steadily and will make major advances when cellulosic biomass to ethanol technology is commercialized.

By treaty, the U.S. is obligated to reduce emissions of greenhouse gases to 1990 levels by 2000. Since ethanol is produced from biomass feedstocks which are part of the natural carbon cycle, using ethanol will help to meet the goal of stabilizing greenhouse gas emissions.

Use of ethanol increases the energy efficiency of aircraft. Gasoline has 125,000 Btu per gallon versus 75,000 Btu per gallon for ethanol. Therefore, based on energy content alone, a range reduction of 40% should be experienced using ethanol. However, because ethanol burns with more complete combustion, in even the worst case, the loss of range is only 25%.

Ethanol is so resistant to knocking that it is possible to greatly increase an engine's compression ratio, thus increasing its thermal efficiency and reducing the aircraft's loss of range. In testing, an aircraft powered by an engine with a low compression ratio (7:1) experienced a 25% loss of range when fueled by neat ethanol. An engine with 8.5:1 compression ratio showed a loss of range of 15%. The engine which powered the aircraft used for the transatlantic flight on ethanol was modified, having its compression ration increased to 10.5:1 to take advantage of ethanol's resistance to detonation; its range loss was only 10%. Compression ratios for ethanol fueled aircraft are likely optimized at about 12.5:1.

Section 5. Cost and Economic Considerations

The cost of modifying an aircraft to run on ethanol will be relatively inexpensive. It is expected that the cost will be recoverable through reduced operating expenses in less than a year.

The price for ethanol is expected to be very competitive with Avgas. Leaded 100 octane aviation fuel sells at a premium in comparison to automotive fuel, and ethanol will maintain a similar margin. The price of ethanol, however, is predicted to remain steady over the next few years because of better technologies and increasing capacity even though the price of the feedstocks will increase (until such time as low-cost cellulosic biomass becomes a viable feedstock). At the same time, the cost of Avgas is expected to increase as the petroleum companies respond to pressure to remove lead from gasoline. Aviation ethanol will be sold at a premium versus auto gas, but at a discount versus reformulated lead-free Avgas.

However, the cost of operating an aircraft will be considerably lower on ethanol. A significant portion of the cost of operating an aircraft is the cost of periodic engine overhauls. As has been stated above, it is expected that the TBO for an aircraft using ethanol can be doubled. This will result in major savings.

Aviation Gasoline

| | |
|---------------------------------|-------------|
| Gate Price: | \$0.85/gal. |
| Fixed Base Operator (FBO) Price | \$1.20/gal. |
| Pump Price | \$2.00/gal. |

A Cessna C-152 with a Lycoming 235N2C engine on Avgas gets approximately 17 miles per gallon.

At 105 miles per hour, cost per mile = \$0.1176/mile

Time between overhaul on Avgas is 2,000 hours

Cost of overhaul is approximately \$15,000.00 per 2000 hours

Therefore, engine operating costs = \$7.50/hour or \$0.0714/mile

Total operating costs = \$0.1176 + \$0.0714 or \$0.189/mile

Ethanol (Current)

| | |
|------------|---------------------|
| Gate Price | \$1.25/gal. |
| FBO Price | \$1.65/gal. |
| Pump Price | \$2.35/gal. |
| Tax Credit | <u>-\$0.54/gal.</u> |
| | \$1.84/gal. |

C-152 with 235N2C engine on ethanol gets approximately 15 miles per gallon.

At 105 miles per hour, cost per mile = \$0.1206/mile

Time between overhaul on ethanol is 4,000 hours, with a top overhaul at 2,000 hours costing \$1,000.00

Cost of overhaul approximately \$16,000.00 per 4,000 hours.

Therefore, engine operating cost = \$4.00/hour or \$0.038/mile

Total operating costs = \$0.1206 + \$0.038 or \$0.1586/mile

It costs \$0.0304 less per mile (\$0.456 less per gallon) to operate on ethanol.

So, for example: Based on an average of 800 hours/year at 105 mph (84,000 miles per aircraft/year), the fleet of 18 aircraft used to train Baylor University/Texas State Technical College students will save \$51,408 per year using ethanol.

It should be emphasized that these calculations pertain to the current situation. With pressure to get the lead out of Avgas (raising its cost) and new production processes for ethanol leading to a downward trend in the cost of the fuel, the economic advantages can only improve in the future.

Section 6. Commercial Potential and Market Considerations

Once the basic infrastructure is established, the use of ethanol as an aviation fuel should be considered commercially viable. If, as is expected, leaded Avgas is phased-out in the next few years, a significant market for ethanol will exist made up of planes that can not use low octane fuel. These planes use approximately half of the Avgas sold in this country, and at this time, there is no viable alternative to leaded Avgas, except ethanol.

As has been stated above, ethanol has significant safety, performance and technical advantages over Avgas. In addition, as was explained in the previous section, because of the increased TBO made possible by using ethanol, the cost of operation of an average ethanol fueled plane is expected to be the equivalent of \$0.46 per gallon less than for a aircraft using Avgas. This should provide a significant economic inducement.

The only barriers to entering this market are the: 1) The need for FAA certification testing of as many aircraft as possible; 2) Lack of public knowledge about ethanol as an aviation fuel; and 3) The need to establish an ethanol distribution network for airports.

The lack of knowledge about ethanol's potential as an aviation fuel is being overcome through a continuing series of demonstrations and educational programs. The most significant action in this respect has been aerobatic performances by Dr. Max Shauck in an ethanol powered airplane at airshows throughout the United States and the world. This is being reinforced by the Vanguards Squadron a group of pilots flying formation aerobatics in ethanol powered aircraft at airshows throughout the United States

Through these combined efforts, the first steps to establish an engine conversion and a fuel distribution system for ethanol will be taken. RAFDC hopes to be able to take advantage of the extensive existing distribution system for ethanol used in automotive fuel and of the work being done to establish E85 fueling stations. With a coordinated effort, it should not be difficult to adapt this system so that it can also supply airports. A number of aviation fuel distribution companies have expressed a willingness to sell ethanol.

The work done under this program will also rapidly increase the number of airframes and engines certified on ethanol and allow RAFDC to pursue many segments of the piston powered general aviation market more quickly than would otherwise be possible.

The first non-governmental markets to be targeted will be the approximately 40,000 aircraft that routinely operate out of and return to the same base. These aircraft are in fleets such as flight schools and agricultural aviation and are estimated to use 40 to 50 million gallons of fuel per year. It will be relatively simple to ensure that availability, at designated airports, of ethanol for any cross country flights. Significantly, the first two airframes to be certified using ethanol will be the Cessna 152 and the Piper Pawnee. The Cessna is the most popular training aircraft in the United States and the Pawnee is one of the most popular agricultural spray aircraft.

Renewable Aviation Fuels Development Center (RAFDC)



Department of Aviation Sciences

0:00:00

Renewable Aviation Fuels Development Center (RAFDC)



Department of Aviation Sciences

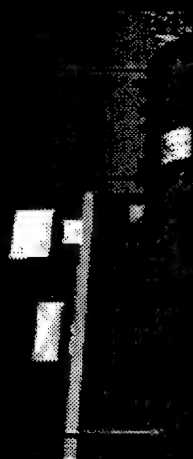
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Renewable Aviation Fuels Development Center (RAFDC)

Department of Aviation Sciences

0:00:03

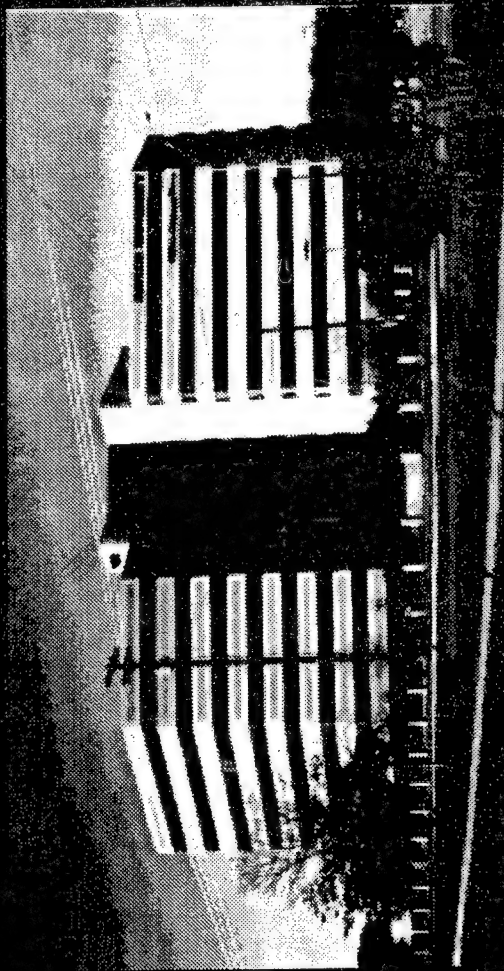
Renewable Aviation Fuels Development Center (RAFDC)



Department of Aviation Sciences

0:00:04

Renewable Aviation Fuels Development Center (RAFDC)



Department of Aviation Sciences

0:00:05

Mission:

To establish renewable fuels, Ethanol, ETBE, and biodiesel, as fuels for the general aviation piston engine fleet and for the turbine engine fleet.

0:00:07

Urgency:

The Federal Aviation Administration, aircraft manufacturers, engine manufacturers, professional aviation organizations and the oil industry are attempting to develop an alternative to the leaded aviation gasoline (AVGAS) used in today's piston engine aircraft.

0:00:10

A temporary waiver from the U. S. ban on lead in gasoline has been granted by the Environmental Protection Agency to general aviation. For economic and regulatory reasons, development of an unleaded aviation fuel will be necessary in the next few years.

- 1. To avoid lead contamination, fuel suppliers will not be able to transport leaded fuels in either pipelines or tankers used to carry unleaded fuels.**

A temporary waiver from the U. S. ban on lead in gasoline has been granted by the Environmental Protection Agency to general aviation. For economic and regulatory reasons, development of an unleaded aviation fuel will be necessary in the next few years.

2. In the future, used oil from engines using leaded gas will likely be classified as toxic waste.

A temporary waiver from the U. S. ban on lead in gasoline has been granted by the Environmental Protection Agency to general aviation. For economic and regulatory reasons, development of an unleaded aviation fuel will be necessary in the next few years.

3. The Montreal protocol requires elimination of all use of Ethyl-di-bromide by 1998. This lead scavenger is necessary in any engine using lead additives.

A temporary waiver from the U. S. ban on lead in gasoline has been granted by the Environmental Protection Agency to general aviation. For economic and regulatory reasons, development of an unleaded aviation fuel will be necessary in the next few years.

4. According to the most current public information, existing alternate Octane boosters cannot achieve the standard 100 octane. A substandard octane fuel now under consideration could not be used in certain aircraft engines which consume almost 1/2 of the fuel used today.

A temporary waiver from the U. S. ban on lead in gasoline has been granted by the Environmental Protection Agency to general aviation. For economic and regulatory reasons, development of an unleaded aviation fuel will be necessary in the next few years.

5. Increased use of alkylates in the new reformulated gasolines for automobiles will cause the price to increase and could result in supply shortages for their use in avgas production.

A temporary waiver from the U. S. ban on lead in gasoline has been granted by the Environmental Protection Agency to general aviation. For economic and regulatory reasons, development of an unleaded aviation fuel will be necessary in the next few years.

6. Piston aviation engines emissions are not yet regulated. Volatile organic compounds and Nitrogen Oxides are being investigated by EPA.

Ethanol: The Alternative to Aviation Gasoline

The reliability of ethanol as an aviation fuel
has been proven:

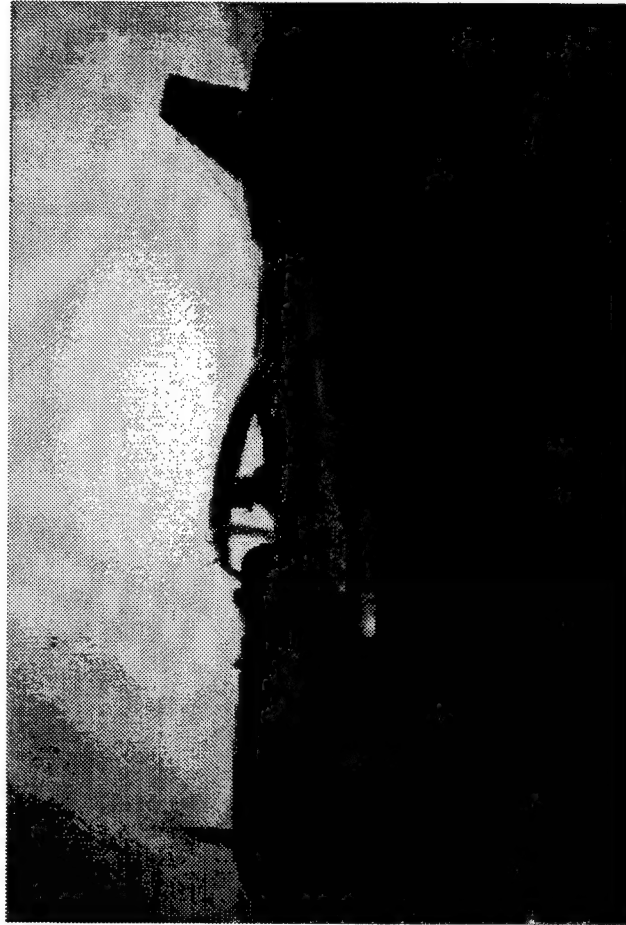
Over 2500 hours of flying on ethanol
accumulated in:



single engine trainers,

0:15:10

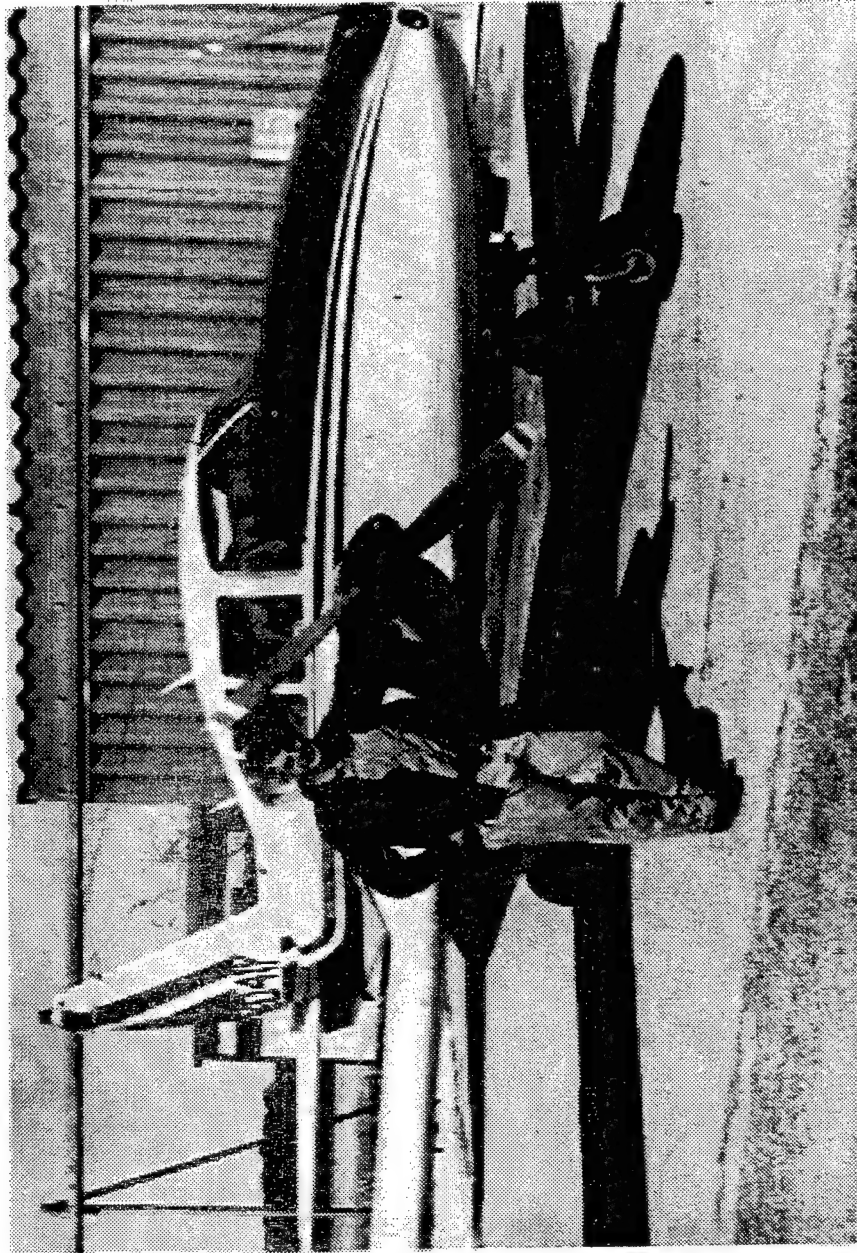
Over 2500 hours of flying on ethanol
accumulated in:



high performance single engine aircraft,

0:16:60

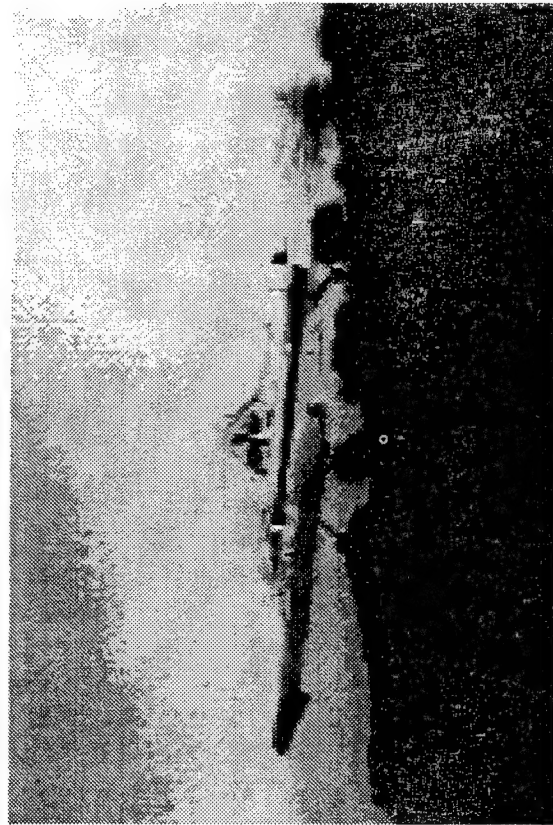
Over 2500 hours of flying on ethanol
accumulated in:



multi-engine aircraft,

0:18:10

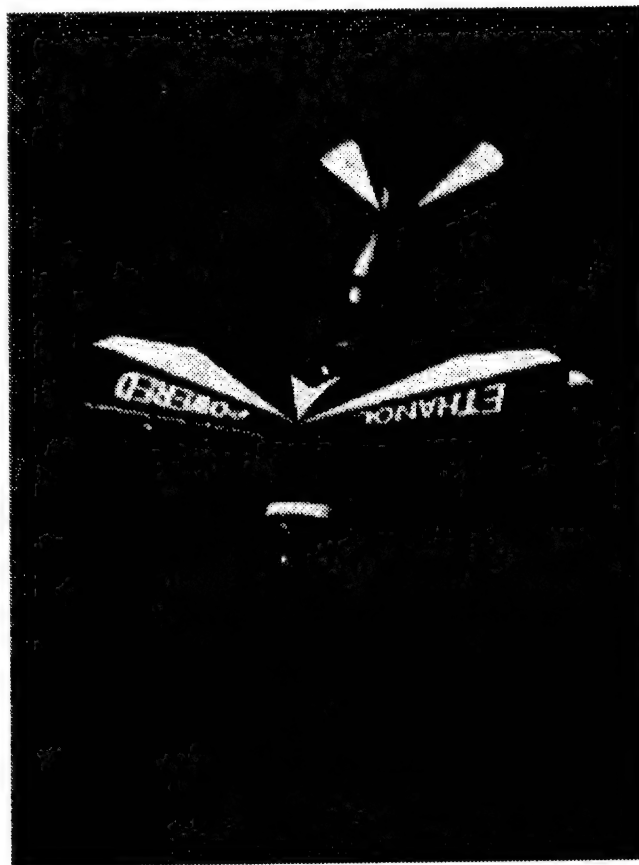
Over 2500 hours of flying on ethanol
accumulated in:



agricultural aircraft

0:19:60

Over 2500 hours of flying on ethanol
accumulated in:



and aerobatic aircraft.

0:21:10

Aerobatic demonstrations have been flown on ethanol at the biggest airshows around the world.



Brazil

Attention
Circus
Le Cirrus
VR 20
Le Cirrus VR 20
Le Cirrus VR 20
Le Cirrus VR 20

Le Cirrus VR 20
Le Cirrus VR 20
Le Cirrus VR 20
Le Cirrus VR 20

Le Cirrus VR 20

REPRO,
LE MUSICAL



France



USA

Italy

0:24:10

Five long distance records flights
on ethanol were officially
recognized by the National
Aeronautics Association.

0:25:60



The first transatlantic flight on ethanol fuel was awarded the Harmon trophy in a ceremony at the White House. The Harmon trophy is the highest award in aviation. Previous recipients include Charles Lindbergh, Amelia Erhart and Chuck Yeager.

0:27:10

RAFDC's three areas of concentration:

1. Certification of aircraft engines and airframes on ethanol.
2. Research and development to improve the efficiency , performance, and reliability of aircraft engines on alternative fuels.
3. Education to increase public awareness of alternative fuels in aviation.

Quit

Continue ->

0:34:26

Education Demonstrations Implementation

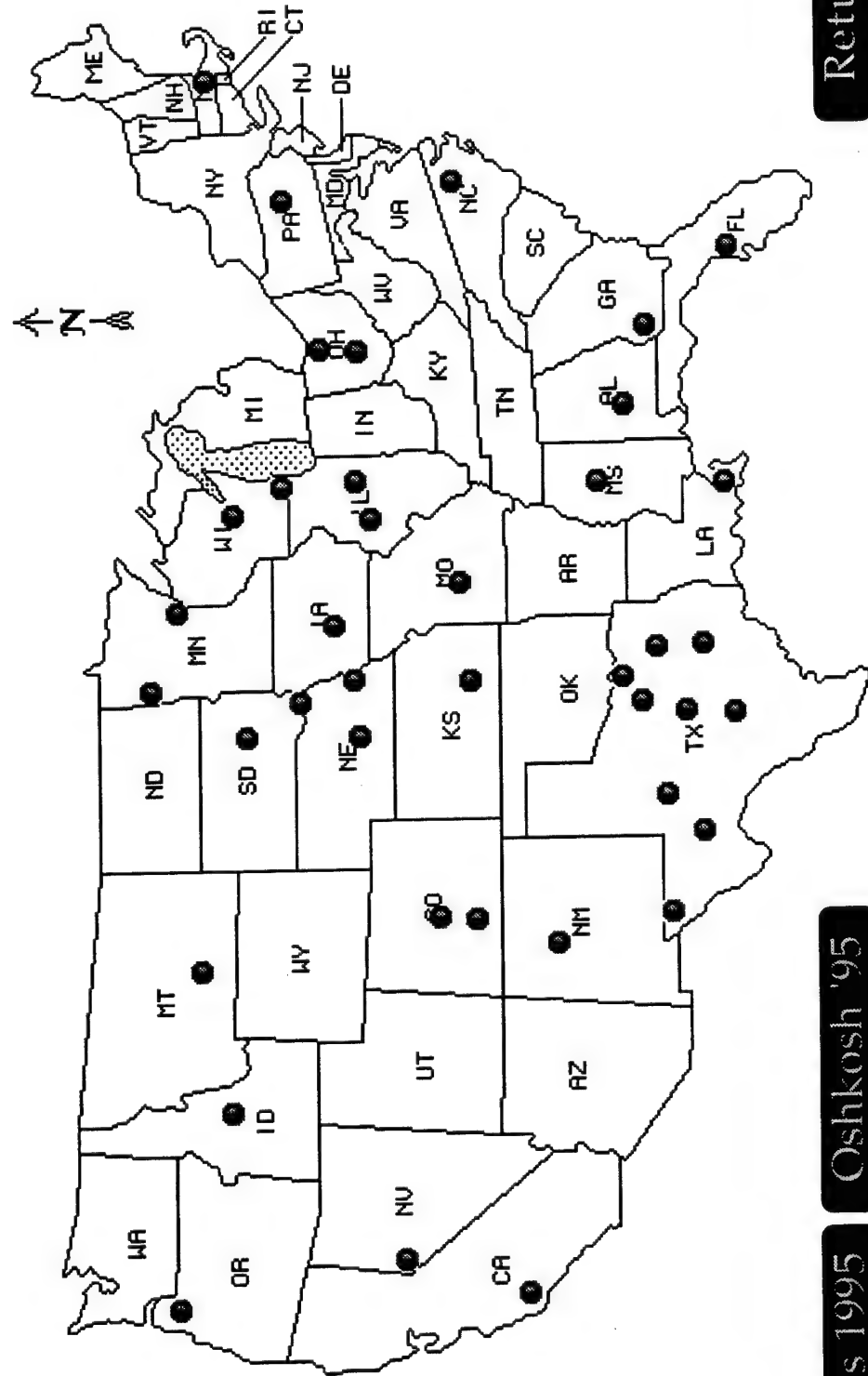
Demonstrations and presentations including aerobic demonstrations, lectures, forums, workshops and exhibits.

Highlights

Return

1:32:89

Demonstrations and presentations including
aerobatic demonstrations, lectures, forums,
workshops and exhibits.



Return

Paris 1995 Oshkosh '95

1:35:89

Paris 1995

1:01:29

Oshkosh '95



1:01:32

CERTIFICATION

RAFDC has completed certification of two series of aircraft engines: the lycoming IO-540 and the lycoming O-235. (images of test stand in gary aerospace, and eci)

Supplemental Type Certificate

Model: 48V9340H
Engine: 48V9340H
Manufacturer: Lycoming Engine Division
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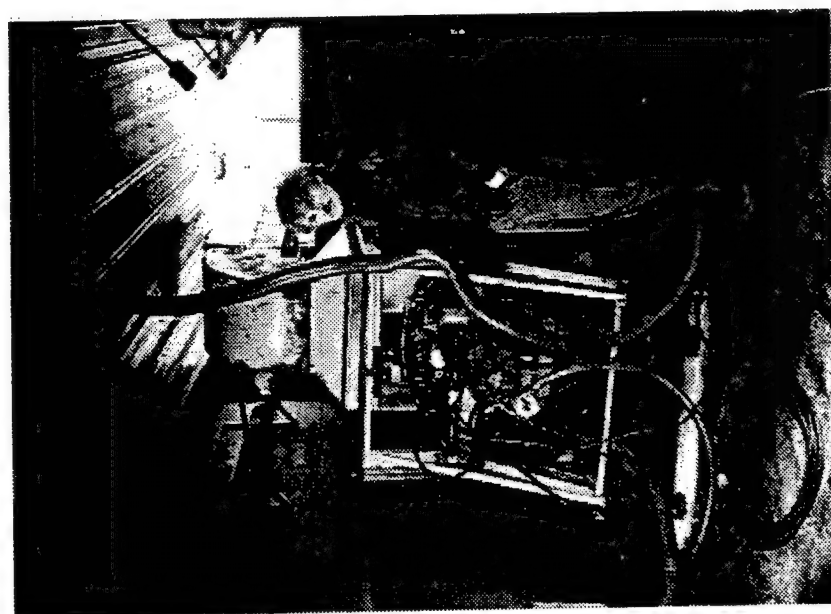
Model: 48V9340H
Engine: 48V9340H
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Engine: 48V9340H
Manufacturer: Lycoming Engine Division

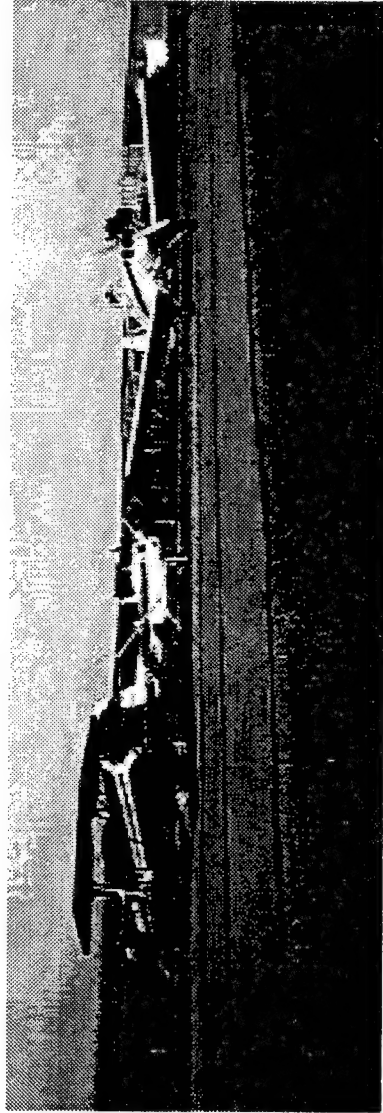
CERTIFICATION

RAFDC has completed certification of two series of aircraft engines: the lycoming IO-540 and the lycoming O-235. (images of test stand in gary aerospace, and eci)



CERTIFICATION

RAFDc is currently certifying
three aircraft on ethanol



Technical
Characteristics of
Ethanol

1:05:86

Technical Characteristics of Ethanol:

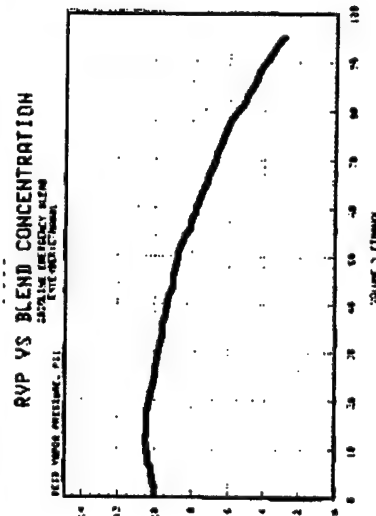
1. Knock resistant characteristics superior to aviation gasoline.



1:08:86

TECHNICAL CHARACTERISTICS OF ETHANOL:

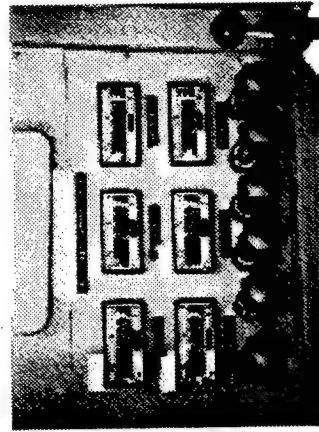
2. Low Reid vapor pressure of denatured ethanol (3.0) responsible for higher resistance to vapor lock and evaporative emissions. Cold start problem solved with the addition of a small (1/2 gallon) tank of gasoline used as prime. Simpler solutions undergoing testing are proving effective.



1:10:36

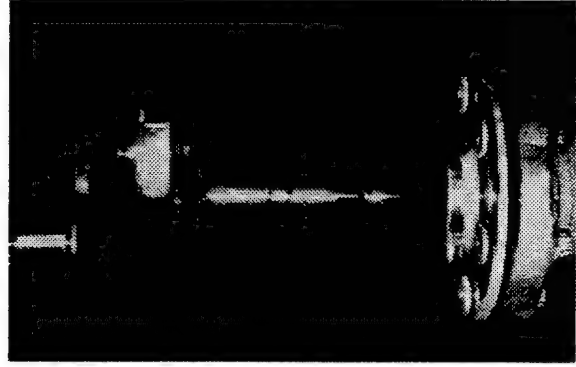
TECHNICAL CHARACTERISTICS OF ETHANOL:

3. Engines run cooler on ethanol.



TECHNICAL CHARACTERISTICS OF ETHANOL:

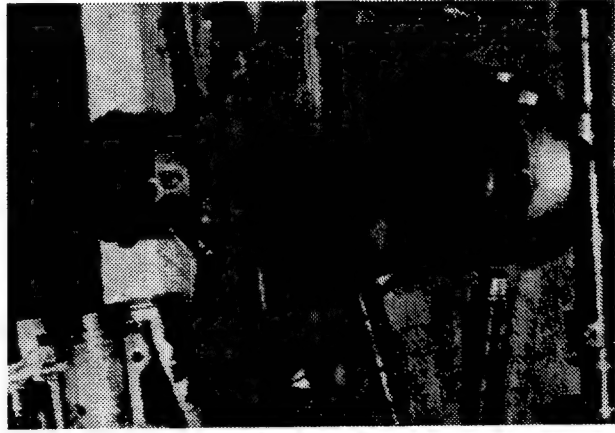
4. According to southwest research in San Antonio, Texas, denatured ethanol exhibits slightly better lubricity than avgas. These results were confirmed by the certification tests which showed significantly less engine wear than in similar tests on avgas.



1:13:36

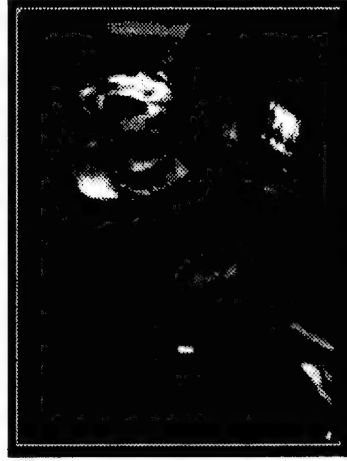
TECHNICAL CHARACTERISTICS OF ETHANOL:

5. Internal build up of combustion by-products is virtually non-existent. This results in decreased engine wear.



TECHNICAL CHARACTERISTICS OF ETHANOL:

6. The FAA designated engineering representative (Der) conducting the certification tests estimated that time between overhaul could be safely doubled on ethanol as a result of smoother, cooler running and cleaner burning. RAFDC is developing tests to verify this conjecture.



1:16:36

TECHNICAL CHARACTERISTICS OF ETHANOL:

7. Loss of range due to the lower heating value of ethanol when compared with avgas. In aircraft with low compression engines (7:1), as much as 25% range is lost. As the compression is increased, the difference in range decreases. The aircraft flown across the atlantic on ethanol had a 10.5:1 compression ratio, and only experienced a 10% loss in range.



1:19:36

RESEARCH

1:22:37

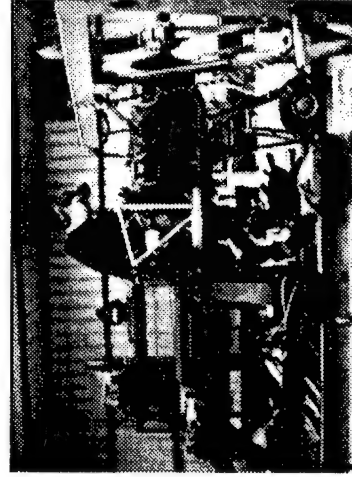
RESEARCH

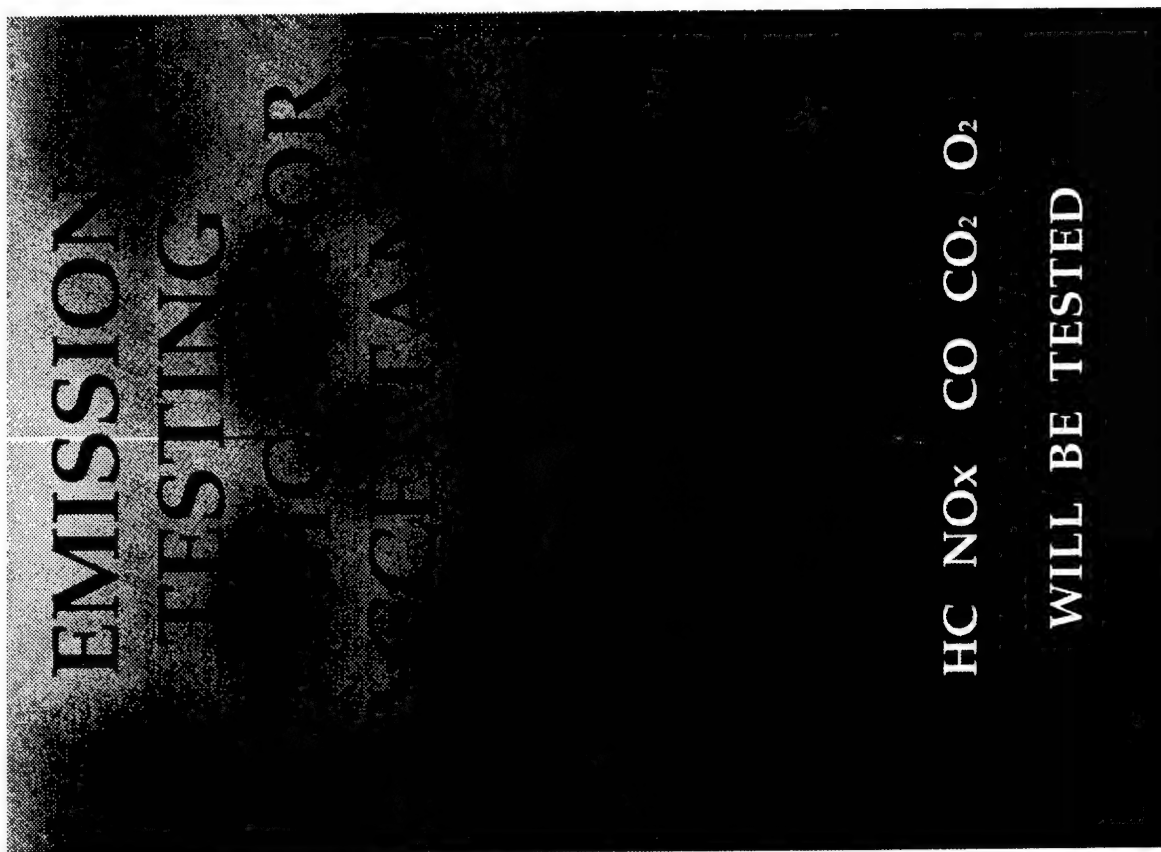
FAA research grant:

1. Improvement of existing engine efficiencies
2. Emission testing
3. ETBE and biodiesel as aviation fuels

Additional engine modifications to be tested:

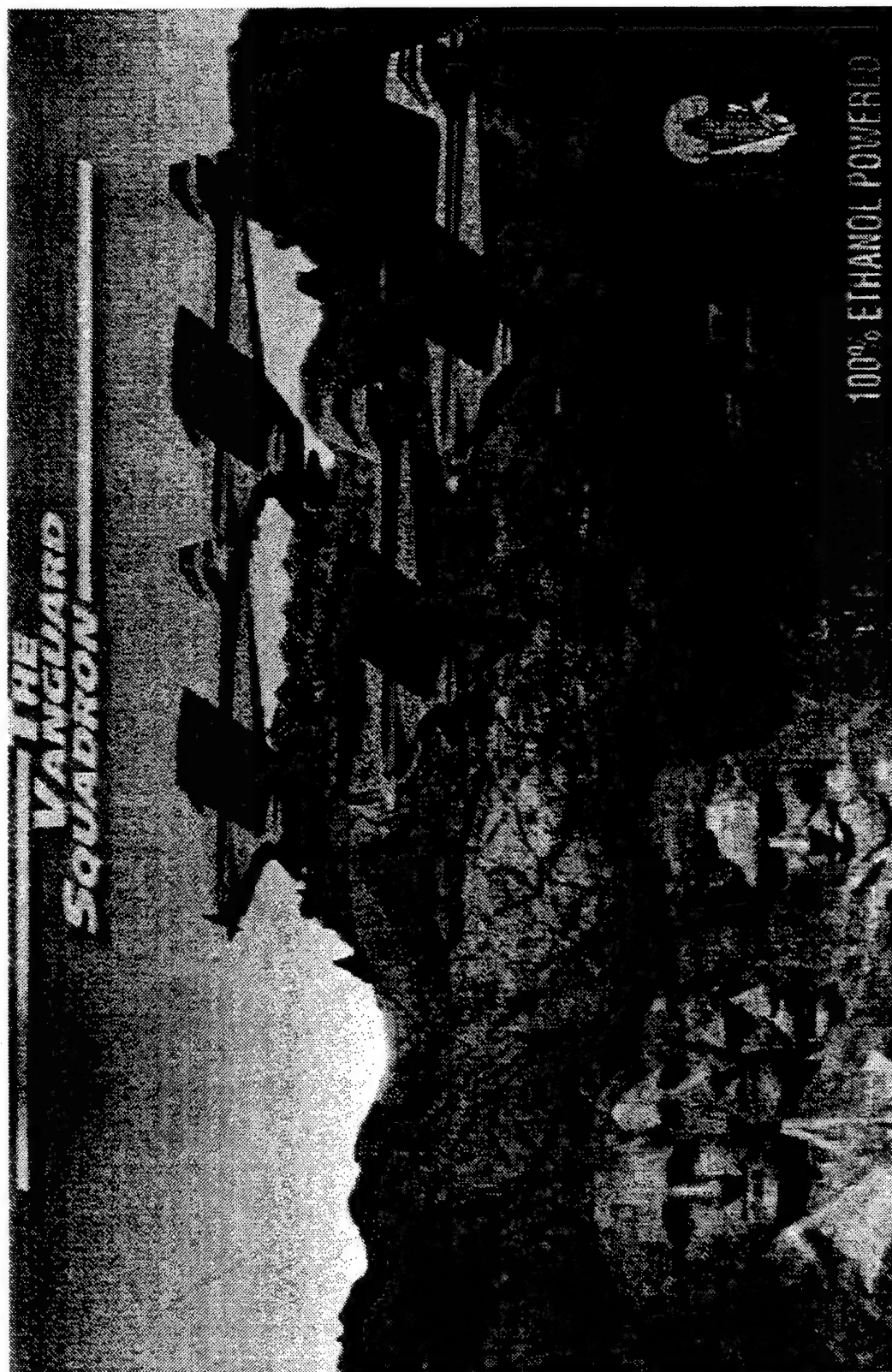
- higher compression ratios
- changes in ignition timing
- different cam geometries





1:31:37

IMPLEMENTATION



0:34:26

IMPLEMENTATION

Development of initial
fuel distribution system:

- Training Schools
- Ag Operators

0:34:27

ECONOMICS

- Costs of Aviation Gasoline vs. Ethanol-price trends
- Extension of TBO
- Benefits to domestic economy

New Activities

REASONS:

high octane fuel

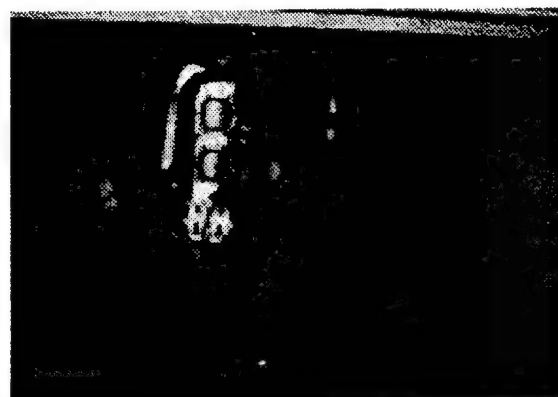
in TU

high octane

environmentally

economically

pet

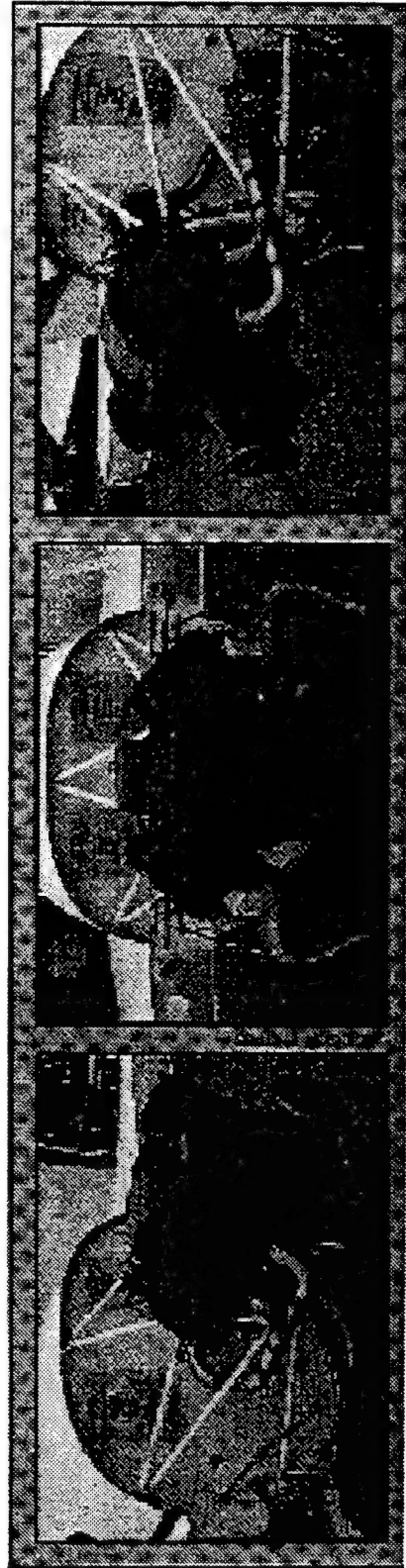


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New Activities



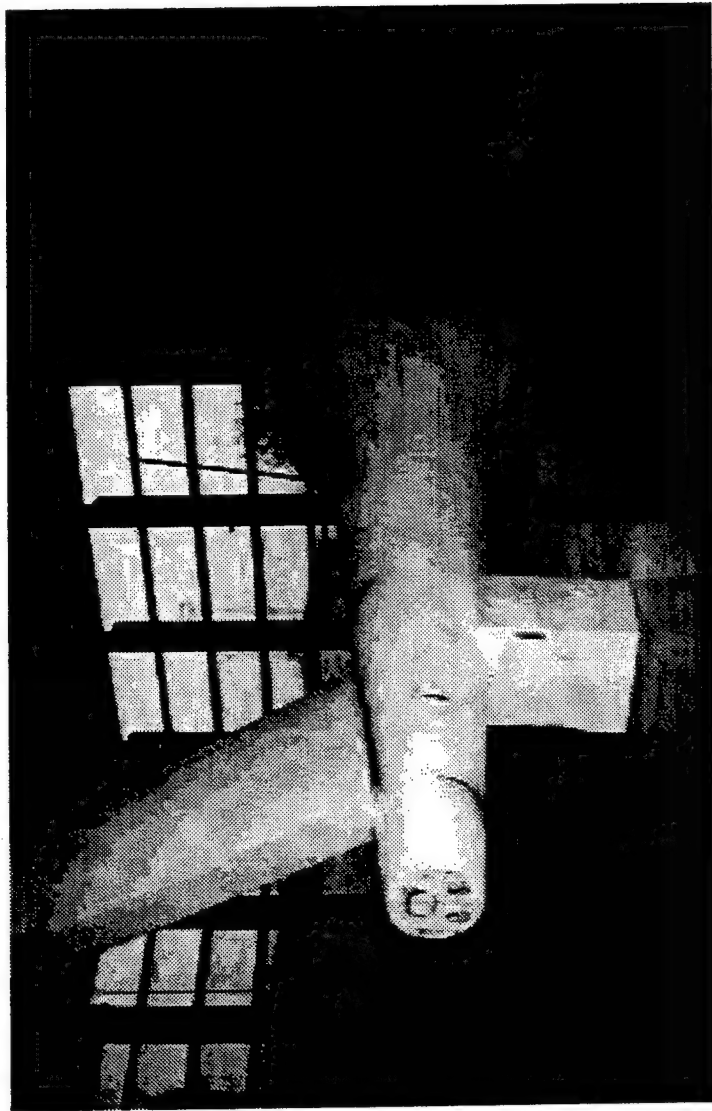
Recent development of
diesel aviation engines



0:38:77

New Activities

•New Aircraft • New Engine •New Fuel



0:40:27

New Activities

Fleet of aircraft powered by renewable fuels to develop 3D air pollution maps.



0:41:77

POTENTIAL

Piston engine fleet:
305 million gallons/year



Turbine engine fleet:
16 billion gallons / year



0:43:27

Biofuels

- renewable
- cost competitive
- low environmental impact
- domestically produced

Petroleum

- finite
- hidden costs
- environmentally destructive
- over 50% imported

**Why have we not
reduced our dependence
on petroleum??**

0:46:27

Obstacles to Implementation

- Economic powers influence on energy policies
- Public Apathy - Complacency
- Public Ignorance - Procrastination

0:47:77

Do you
remember
1973 ?

0:49:27

Do you
remember
1973 ?

In 1973, we imported
less than 40% of our
petroleum.

0:50:77

Do you
remember
1973 ?

Today, 53% of our
petroleum is imported.

What can we do?

- Education
- Action

0:53:77

Fuel is the lifeblood of our country. Aviation can and should take the lead in adopting renewable, domestically produced, high performance, clean burning, economical aviation fuels, which will reduce the trade deficit, stimulate the growth of new industry, and benefit the environment.

0:55:27

It's a big challenge!!!

Be part of the
solution!!!

0:56:77

International Conference on Alternative Aviation Fuels



BAYLOR
UNIVERSITY

November 2, 3 & 4, 1995

0:59:77

EXPERIENCES WITH METHANOL-POWERED AIRCRAFT

GORDON COOPER
PRESIDENT
GALAXY AEROSPACE MANAGEMENT

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Summary of Gordon Cooper's Remarks
to the First International Conference on Alternative Aviation Fuels

Gordon Cooper started out his remarks by saying there is no reason we can't have airplanes flying on alternative fuels. He then gave a short history of the use of ethanol and methanol, talking about Henry Ford's efforts to establish ethanol as an automobile fuel and how alcohols were used as fuels during WWII. He also mentioned that the Germans had planned to use a piloted V2 rocket, fueled with ethanol, to drop bombs on New York City. Cooper noted that all the alcohol fuels technology developed during the war disappeared as soon as it was over.

He then gave a short history of his involvement with alcohol fuels, recounting how, in the 1970s, his company had run engines with compression ratios of above 19:1 on methanol and how this had doubled their horsepower and doubled the miles per gallon. According to Cooper, it was as a result of this work that he ran into Bill Holmberg and secured DOE sponsorship for an alcohol fuels caravan which went from San Francisco to Washington, D.C. It was on this trip that he met Bill Painter. Painter owned a Super Cub that he was converting to methanol and the two of them decided to join forces to certify it, which was the reason that Cooper became involved with alcohol fuels in aviation.

Next, Cooper responded to some of the alcohol horror stories he had heard over the years. In response to the claim that using alcohols would result in reduced range Gordon stated that the Super Cub handbook said that the plane would have 4.2 hours endurance but he was getting 5 - 5.5 hours on methanol. He also said that according to the handbook, the service ceiling for the airplane was 13,000 feet but he and Painter had conducted a number of flights at altitudes as high as 25,000 ft. and that they had experience no icing problems when doing so.

In response to the claim that using alcohols resulted in cold start problems, he claimed to have experienced no cold start problems, with restarts down below zero causing no problems. He also said that alcohols are safer than Avgas. According to him, it is possible to extinguish a methanol fire with water and it burns with very low peripheral heat so you are less likely to be hurt. He also stated that methanol would not ignite, as a hydrocarbon would from vapors being near a flame. Gordon claimed to have shot bullets through cans of methanol which did not explode.

With respect to stories about material compatibility problems, Cooper said that they had tested many materials and that the only materials he tested that proved to be incompatible with methanol were low density viton materials which aren't used much anyway.

With respect to various stories about the toxicity of methanol, Cooper claimed that testing by a laboratory showed no indications that methanol's combustion byproducts were carcinogenic. He also stated that, with reasonable care, methanol is not unsafe to handle.

He rejected claims that using alcohol fuels causes excess wear to valves and combustion chambers. He said that he and Painter did over 2,000 hours of flying under the harshest of conditions and after the engine was disassembled for inspection they found them to be in such good shape that they could have sold the parts back to the store as new.

Cooper closed by saying that we haven't made much progress since he did his work 20 years ago and that we need to get together and see what we need to do, to really make progress.

**WORLDWIDE ALTERNATIVE FUEL EXPERIENCES:
BRAZIL**

**PLINIO NASTARI
PRESIDENT
DATAGRO, LTD. (BRAZIL)**

**FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY**

The Brazilian Experience
Dr. Plinio Nastari
Datagro, LTD.

I would like to use the few minutes that we have just to say that Brazil is probably the country with the largest potential for the utilization of what is being done here in Waco. I am going to present to you some facts, some distortions, some of the reasons why we believe so. First, the facts. The price of Avgas in Brazil at retail is \$3.30 per gallon, compared to automotive gas at \$2.51 and the price for neat hydrated ethanol at \$1.79 per gallon.

So Avgas price is obviously very high, and this is one of the reasons that general aviation is not developed as it could in Brazil in the past few years. One of the reasons the price is so high is that Avgas in Brazil is produced from only one refinery. There are only 13 large refineries in Brazil and this product is produced in only one and has to be distributed nation wide.

We have had, third fact, many fuel stability problems with Avgas. And, all these factors have led to a very small dependent of Avgas over the years. In 1994, total demand for Avgas was only 16.5 million gallons. Which is 20 times less than in the U.S.

On why Brazil has a great potential for application of this technology. First of all, Brazil is a continental country -- in size larger than the U.S. except for Alaska. Second, commercial aviation is very expensive in Brazil, basically because of taxation. Therefore, there is a lot of room for general aviation to grow.

I am going to give you a few examples of flying tariffs in Brazil so you have some idea of how expensive commercial aviation is. The ticket from San Palo to Brasilia, which is only one hour and 15 minutes away, costs \$520. This is pretty much the same as we would pay for a flight from San Palo to Miami. Or, a ticket from San Palo to Porta Legre (?), the southern most state in Brazil, is 17% more costly than flying from San Palo to Buenos Aires, twice the distance.

The distortions that this has caused: First, the high price of Avgas has unnecessarily pushed users towards more expensive aircraft that use aviation kerosene or jet fuel. Which is price at a much lower level at \$0.95 per gallon in Brazil. And, the second distortion is that since general aviation is not made viable easily, commercial aviation is being subsidized by local prefectures. Mayors in small cities pay subsidies to small regional flight companies to fly to their cities.

So why would Brazil be such a nice country to adopt this technology? And, why is it so interesting that even though the first neat ethanol engines in Brazil were developed at the aeronautical technological center, even though the technology was never adapted to aviation? Well, I have indicated already early this morning one reason, and attempt to overcome that. We, in 1988, we saw the pioneer of the ethanol industry in Brazil, Lamartine Navarro, buying and flying a decathlon from Max Shauck, from Waco to Brazil. He gave this airplane free to the CTA so that they would test the technology -- but nothing happened. Still the advantages are clear and we are hoping that as the research has proceeded here at Baylor we are going to be able to transfer this aviation technology -- overcoming the CTA problems we have had in the past.

The main reason why we have a competitive advantage in Brazil for the use of these fuels is because we already have a network for ethanol distribution in place, with over 25,000 fueling stations already selling neat ethanol all over the country. We have 370 ethanol producers spread around the county producing, and backing, the fuel supply system. We have already installed quality control systems. And, we have changed the fuel specification for ethanol to adopt this fuel for the use in engines that utilize electronic fuel injection systems.

And we see that the first applications for this technology will be agricultural use. In sugar cane firstly. Because, producers are selling their alcohol for \$1.30 per gallon and that would be the opportunity cost that they would have, compared with \$3.30 per gallon. Further more, ethanol is a stable fuel.

Why is ethanol fuel than fossil fuels? First of all, studies in Brazil have proven that ethanol competes with oil products when oil is priced between \$19 and \$21 dollars per barrel. Ethanol is very important in Brazil and is highly regarded by the whole society as being a powerful strategy for job creation. Seven percent of jobs in the state of San Palo, which is the most developed one in Brazil, are in the agricultural sector. And, of those 7%, 40% are in the ethanol production. Investment per job is very low compared with other activities. \$11,000 per job in ethanol compared with \$30,000 per job in other agriculture and \$90,000 per job on average in all of Brazil.

Seeing that we will have a job deficit of 20 million by 2000, multiply 20 million by \$90,000 and you get \$1.8 trillion of investment needed. I must say that represents four times our domestic product. And we have to invest that in five years. We are going towards becoming a Bangladesh very quickly. Ethanol is not going to solve our problems by itself. But it is part of a strategy to alleviate that problem. We have invested in Brazil \$11.3 billion dollars over all to create an industry that displaces 215,000 barrels of oil per day. And this industry, with no additional investment, has saved the country already \$27 billion in foreign oil imports. And every year without any additional investment it saves the country between \$1.5 and \$1.6 billion additional dollars.

And finally in environmental terms, I will not go over all the specifics behind CO, HC and NOx. But in a much broader view, which is currently being raised by the Climate Convention. After the Rio conference in '92, the UN which is the repository for the convention, of the frame work agreement on climate change, has built a body of experts, called the IPCC -- the Intergovernmental Panel on Climate Change. And, IPCC has just completed its report and the summary to policy makers has been approved just this past October 13. And the whole study is going to be presented for review at the IPCC plenary meeting in Rome, next December 11.

I would like to read to you what is the recommendation that this body of experts is giving to the 172 country leaders that have signed the climate convention. "Possible actions that policy makers can consider are: 1) Energy efficiency measures; 2) Phasing out of existing distortionary policies, such as non-internalization of environmental costs; 3) Implement cost-effective fuel switching measures from more to less carbon-intensive and carbon-free fuels, such as renewables; 4) Implementing measures to enhance sinks or reservoirs for greenhouse gases, such as improving forest use management and land use practices; 5) Encouraging forms of international cooperation to prevent greenhouse gas emissions, such as implementing coordinated carbon or energy taxes. Activities implemented jointly and tradable quotas;"

I would like to say that the state of San Palo is the eve of establishing a carbon tax on gasoline and diesel with total exemption for alcohol.

"6) Conducting technological research aimed at minimizing emissions of greenhouse gases from continued use of fossil fuels and development of commercial non-fossil energy sources."

Well, the climate convention, therefore, brings a new dimension to this whole energy issues. It brings the possibility of internalizing the fuel prices. The hidden, so difficult to measure, environmental benefits. I think this is what is changing. And, this is what will make the changes happen.

So we don't think the solution is going to be gasohol. For all the reasons that gasohol poses to aviation: condensation and phase separation. We don't think the solution is going to be Avgas for

all the reasons that have been raised here and have been so well pointed [out] by Todd Sneller before he left. How are you going to solve the problems of lead and the problem of aromatics?

Ethanol is available in Brazil. The application is very easy. And we are very excited to be here in Waco and we should only praise and compliment the efforts that you in the U.S have been able to accomplish.

ALTERNATIVE FUELS IN EUROPEAN GENERAL AVIATION

MATS EKELOUND
CROSSROADS CONSULTANTS
SWEDEN

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Biography

Mats Ekelund has a BBA and has been working in the alternative fuels industry as a consultant since the early 1980ies. He has conducted several studies and has lead hardware projects, mainly in the road vehicle industry.

Some of Mr. Ekelunds clients, beside DOE/NREL, are Amoco, Caterpillar, Mercedes, Volvo, International Energy Agency, UN/ECE, British Gas, Russian GazProm and the Swedish Ethanol Development Foundation.

Contents

- 1 **Background**
 - o History
 - o Objective
 - o The Task
- 2 **Europe**
 - o The three markets
 - o Population, Energy & Environment
 - o Aviation Industry & Fuels
 - o Legislation and Taxes
 - o Conventional Fuel Industry
- 3 **New Fuels**
 - o Unleaded Gasoline
 - o Gaseous fuels
 - o Alcohols
 - o Other
- 4 **Small aircraft industry**
 - o European manufactured
 - o Imports
 - o The engine - the heart
- 5 **US impact**
 - o Market
 - o Legislation
- 6 **The market awareness**
- 7 **Conclusions**

1. Background

1.1 History

General aviation is, and has always been, a scattered market. Engines that are used in today's Ultra Light and light aircrafts are to a great extent design long time ago testifies of how small the market has been during the last decade(s).

Small aircrafts have been used for pleasure for as long as they have existed and the bulk of the fleet belongs to enthusiastic air-clubs. The professional use of Ultra Light and light aircrafts has varied. Courier, mail, agricultural spraying, photographing and many other industries have been using this un expensive way of getting up in the air and do a job.

From a fuels point, there has always been a leaded fuel in western Europe. The Russian, Czech and Hungarian oil industry have provided low octane un leaded fuel for many years¹.

There is not, and has not been, any environmental involvement in this industry, at least not in Europe - until lately. The historic purpose is pleasure use and for the safe and economic operation of what ever professional use that has been in question.

1.2 Objective

The objective in this report is to provide a general level of information about European General Aviation. It is supposed to present a current situation and be a source for anyone interested to find information upon which contacts can be made and new business as well as development be initiated.

The limit in this report is if the aircraft is piston engine operated or not. The piston engine operations is inside, the jet is outside.

The objective is not to give a complete overview and it is not a scientific study. It contains a substantial research to find the enthusiasts that create a change for a future market, there are also safety aspects related to the lust of extreme trials.

1.3 The task

This report is about and around fuels in European General Aviation. First of all about the things that originates in Europe, secondly about non-European players that operate in Europe, industries etc that make an impact in Europe. For the most, information is given for Western Europe.

¹ Aerotechnich, Cz

2 Europe

2.1 The three markets

Europe consists of three main markets for AVGAS:

- 1) Former Soviet Union, with a declining, but still big production of aviation fuel. It is both leaded and unleaded and the objective, when it comes to development, is to replace AVGAS with other fuels. In this case Propane/LPG is the most focused alternative.

The liquid fuels are less expensive to distribute and more attractive to export for hard currency trade. Gaseous fuels are generally more attractive to utilise domestically.

- 2) Former East Block countries where there is less regulation, not so much flight-for-pleasure and no public debate on environment.

Simultaneously, these countries have a fairly well developed refining industry and as long as lower compression engines are used, the fuel can be unleaded.

- 3) Western Europe, where the development is just getting started after a decade of slow economy, where environment is becoming an issue and where there is an expectation that new technology should reform the engines.

2.2 Population, Energy & Environment

Europe west of the former Soviet Union (FSU) is half the size and virtually twice the population compared with the US. Four times the density of people allow for more efficient public transportation, shorter distances to markets and the European fuel consumption is about half that of the American, per capita. A more efficiency concerned market as fuel is heavily taxed and has been so for quite some time.

The European Community supply just over 50 % of the needed energy from domestic sources. Within its boundaries, this varies of course and the UK is one good example of that. British Petroleum and British Gas are both surplus distributors of energy from a national trade balance point of view. Also Norway, Denmark and the Netherlands are net distributors of oil and gas. The high density of people limits the possibility to explore agricultural areas, forests and fields for energy purposes. This somewhat to the opposite compared with the US, where the

agricultural and forestal area is much larger per capita than in Europe. Non the less, most every country in Europe have a bio energy programme directed towards industrial process energy, heating and to some extend to road- and sea vehicles, not yet toward aircrafts.

A comparison between Sweden and Germany will make the difference a little more obvious. Sweden is the size and shape of California, it has 9 million people and enormous forestal resources. Germany is 2/3 of Sweden in size, but have some 70 million people and are net importers of food. Germany do not have the big forests with only a few exemptions and the space available for growing energy crops is thereby limited. The density of people in the Netherlands is even higher, but the soil is more fertile in average, whereas the situation is comparable. Russia has access to land and farming but trade barriers hinders the utilisation of this source.

2.3 Aviation, Industry and Fuels

After the financial Hausse in Europe, the market started to decline during the second half of the 1980is. The US manufacturers saw a 50-90 % decline in market and survived by changing business to service and overhaul. Europe General Aviation market did not suffer to the same extent. Some 25-40 % reductions in sales seem to be the European manufacturers mutual figure. The market seem to have stabilised and, since medio 1995, there are signs that points towards growth.

The last ten years has not offered much space for technical R&D or development - if that is set as a portion of turn over and not long term product development. The strategy has instead been economic survival. Some manufacturers have attempted to cut them selves a share of a declining market, but few have been successful. Smaller, though important, developments have been done like re-designing the shape, surface and material for propellers. Many companies have been successful in reducing noise, increasing aerodynamics in the propeller wings and reducing weight. Noise around 60 dBa during take of has been measured with a muffler and a modern propeller. The higher efficiency reduces the use of energy per air-mile which has a positive environmental impact. This can also be expressed like longer range per refuelling, a cost- a resource- and an environmental saver.

European Aviation engine suppliers is dominated by the US based manufacturers, except for Ultra Light aircrafts. The aircrafts using Textron Lycoming and Teledyne Continental may have as much as 60-80 % of the European market.

French Aerospaciale for lager aircrafts and Austrian Rotax for Ultra Light aircrafts are the two dominating engine manufacturers in Europe. German Limbach is there

as well as the Czech Aerotechnic and Russian Iljushin. There is no a common European registration for these air vehicles, not even a national in every country.

The European market for AVGAS fuel, in its different occurrences, is not registered either, not even within the oil industry. Shell for instance sell jet-fuel as a Europe wide fuel and headquarters collect statistics. AVGAS is sold as a nation-by-nation sold fuel and the market size is not revealed.

An estimated volume in Western Europe is to 3-400.000 cubic meters (20-25 million gallons). East Europe is difficult to even predict, but maybe 50.000 cubic meters. FSU may be equal to the rest of the former East Block. A very rough estimate² is a European AVGAS-market of 800.000-1.000.000 m³.

2.4 Legislation and taxes

European legislation for fuels and environment is virtually not existing. The normal safety standards and traffic codes are naturally there. Western Europe, nor the former East Block areas legislate on its own on environment or on the fuel specification. The ICAO noise demand is in place but different countries exercise it differently. Germany for instance demand ICAO less 4 dBA(A).

Weather unleaded (UL) AVGAS is allowed or not is a matter of debate, big debate. The criteria is that the engine manufacturer has certified the engine for the UL fuel and that the market opponents, sales and buyer, agree. Thereby, the fuel can be sold to any customer. By labelling at the sales position, the oil company announces the UL version of the fuel. If the buyers buys, than one can claim that there is an agreement as he has chosen a fuel voluntarily.

Further about legislation will be given in section 5.2, where the impact of US legislation will be discussed.

Taxes

Former East Block countries does not have a functioning tax market as all prices has been fees for something, payable to the government. West on the other hand never could make up its mind.

There is an EU directive that generally say that all energy is taxable. The EU 92/82 EEG directive say that all "pleasure flying fuel is taxable". Who measures and what administration can handle this. Some countries have had such legislation previously, but left it because it did cost the government more to collect than the revenue it self brought in.

² Authors calculation, based on interviews with oil companies.

A common European AVGAS price is ECU 0.4-0.45 per litre (US\$ 2.10-2.50 per gallon) and the minimum tax is another ECU 0.3 (US\$ 1,70) which totals ECU 0.7-0.75 (US\$ 4 per gallon).

Seven out of the previous 12 countries in the EU, have negotiated tax free operation for General Aviation (piston engines) and in practice, the operation is tax free - but there are exemptions to that.

During time for taxation, the flight hours went down, clubs closed and the price of an airplane was very low. Negotiators pointed out the safety aspects of reduced flying as skilled pilots became rare. How big an impact this argument had, the story does not tell, but it did.

2.5 Conventional Fuel Industry

Western Europe

Most oil companies operate on the AVGAS market. In Western Europe, the AVGAS 100 LL is the standard fuel. The development has gone from lower octane like AVGAS 80/87, that still exist to some extent, to the now predominant 100 LL.

As with the example from Shell above, the market involvement in this fuel segment is mainly nation based.

The position by individual oil companies on what the next step is varies. Among the European oil companies, many have prepared for a lead-free market and do virtually only wait for legislation or a market demand. One thing the oil companies are trying to avoid is a multi fuel market, it is not big enough for that they say. The double distribution and storage is an investment that the size the market has and its marginals can not pay - they say³.

Conventional AVGAS 100 LL (low lead) may contain up to 0,56 grams lead per litre. This is to compare with the regulation Europe had on lead contents for mobile use of 0,15 grams per litre. Western European automotive gasoline is virtually unleaded today, as lead has been mandatorily replaced by other lubricating materials and octane enhancers.

Central Europe

The history of AVGAS in countries like Poland, Czech- and Slovak Republics, Hungary etc, is that of unleaded fuel. Qualities in use are AVGAS equal 70-85 for the most. Engine manufacturers have produced their equipment based on government

³ Author personal conversation with oil companies, where they have requested individual confidentiality on R&D efforts.

purchase, whereas very little development has been done. In these engines, the heat release is not that big because of lower compression ratio. Lubrication of both inlet and more so on exhaust valve does not require lead.

Russia

This market was easy to cover as Lukoil had a fuel monopoly. Now entrepreneurs grow up and the Russian market is beginning to see other players, like for instance in Moscow at the Vnukovo airport where there is a constant shortage of jet fuel, many small foreign companies operate. AVGAS 80 and 100 LL is otherwise used in Russia.

3. New fuels

3.1 Unleaded fuels

Hjelmco Oil

The European success story is that of Swedish Hjelmco Oil. 1979, Lars Hjelmberg initiated the use of un leaded AVGAS 80/87. US legislation contains a paragraph, a remended from the 1930ies that say that if there is an agreement between sales and purchase, other fuels can be sold as long as there is a valid certification to the fuel in question. This paragraph is heavily questioned in some of the major oil companies but has been in practice for more than 15 years without any law suit.

Hjelmco Oil were blocked by the oil industry who did not want to see a diversification. Hjelmco Oil were interested in buying fuel from larger refineries and mix the final composition in own installations before distribution. Hjelmco Oil claim that no western oil company were willing to sell, whereas they had to go to central Europe where the willingness to sell for hard currency was greater.

Today, Hjelmco oil has a substantial market around the Baltic Sea with shares of tenths of % in some geographical areas. On the two following pages, maps and sales places are pointed out. A replacement for 100 LL is in "pipeline".

The Hjelmco Oil distribution network is substantial. There is an interest in further growth but a reluctance due to US regulations which will be further discussed in section 5.2

AVGAS 91/96 UL (un leaded) is produced from distillates from the production of a high quality AVGAS 100 LL. It has no Benzene, no Sulphur, 1/50 Normal Hexane and less Halogens, whereas the the toxic impact is likely to be lower from this fuel than from AVGAS 100 LL with which it compares. Both fuels meet the ASTM D910 with some exemptions.

| <u>Parameters</u> | <u>AVGAS 100 LL</u> | <u>AVGAS 91/96 UL</u> |
|---------------------|---------------------|-----------------------|
| Rich octane number | min 130 | min 96 |
| Lean octane number: | min. 100 | min 91 |
| Colour: | blue | transparent |
| Scavenger: | 1,2 dibromoethane | no 1,2 dibromoethane |
| Tetraethyllead: | max 2 ml/ US gallon | unleaded |

The matter of combustion chamber deposits does not seem to be solved at this point by any oil company.

Hjelmco Oil sell AVGAS 91/96 at the same price as market price for AVGAS 100 LL on each market.

3.2 Gaseous fuels

Russia has a need to export and aim to sell oil to a large extent. Therefore, the use of gaseous fuels for any purpose is encouraged domestically. The gas industry R&D organisation VNIIGAS are developing the use of Propane (LPG) operated smaller aircrafts and helicopters.

VNIIGAS currently work with seven different design bureaus - i.e. aircraft manufacturers - to introduce Propane as a fuel. The VSHS (BCXC in Russian) company, with a local Dvuratel 9-cylinder engine is manufactured in two prototypes and operate on trial basis.

LNG has been discussed, and aircraft industry official⁴ say it will stop at talking as the storage of LNG is far to big and heavy. Propane is already at that edge.

Propane is really an LPG mixture where the contents of for instance Butane varies as supply and climate vary.

One of the major concerns is that of the low pressure cylinder weight, being about 5 times as high as that of a normal fuel storage. The fuel on the other hand is 0-10 % lighter, which may be giving a small but not sufficient weight reduction.

3.3 Alcohols

Ecofuel out of Italy provide ETBE from their production facility in Ravenna once every year to the Paris Air show, where Max Shauck at Baylor University performs.

⁴ Vladimir Andreev, Professor, Manager Design Bureau, Tupolev Aircrafts.

Alcohols are otherwise not introduced yet. None of the engine manufacturers Lycoming, Continental, Aerospaciale Rotax; Limbach or Volvo have yet received requests for alcohol operated engines, according to their own information. The work performed at Baylor University though, is well known and different manufacturers follow it at different depth.

Sweden, Denmark, France and Austria have ethanol discussions or operations for road vehicles, but not yet in the air. Also in these countries, the Baylor University experiments are followed and used for marketing purposes.

3.4 Other

Other fuels could be RME (Rapeseed Methyl Ester), methanol, and automotive gasoline.

Out of this, only automotive gasoline is used. Rotax require unleaded automotive gasoline 92 (or more) octane (RON) for their two stroke engines. Rotax is a major manufacturer of engines for Ultra Light aircrafts, whereas this market is substantial. No data is available for measuring the size, the local fuel distribution is arranged locally, to the club or to the field. Volumes may be in the 10-20 % range of the European fuel market.

4. Small Aircraft Industry

4.1 European Manufactured

Some 20 to 30 manufacturers of any substantial size operate in Europe. The recession or weak economic growth over the last decade has made the manufacturers reluctant to invest in major development activities. The market decline stopped during the early 1990ies and has, since a couple of years created faith in a market growth.

The last years of development has been focused on propellers, lighter weight materials and a smoother body design. Swedish Hagfors and Austrian HOAC claim that the fuel efficiency increase 20 - 40 % without touching the engine just by body- and materials research and development. These and several other manufacturers are working with, or plan to work with, the new lighter and more modern material.

New material and more sophisticated products cost more. The marketing of the new shape aircrafts therefore address more modern cost benefit analyses methods to promote the use of a product that draws a higher investment. The higher investment does not necessarily mean that the product is more expensive. If professional, the buyer need to compare the return of investment towards his company

depreciation and required return time for the investment. Austrian HOAC use this method of economic calculation in their marketing, where they compare their own product with a competitor who operates on the same market.

From a business point of view or from an economic theory point of view this is not unique at all. For the Ultra Light aviation industry, the development that has taken place over the last years requires a development of professional economic calculation methods.

Below, again from Austrian HOAC, an example of investment graphs to promote a higher price product.

4.2 Imports

Lycoming and Continental dominate the European General Aviation market. Their estimated share is between 60 and 80 %, depending on if sales are measured or if engines in operation is measured. French Aerospatiale is really the only West European competitor. Some smaller manufacturers in Europe is, and have been, trying to take a market share.

During the last 10 years, not much engine developments has been done by those who sell to Europe. There has not been a demand, they claim and the sales has not allowed for any major changes.

The issue of unleaded AVGAS has been one of them that has drawn attention. The slow years in the late 1980ies and the beginning of the 90ies have involved tests and engine adjustments to provide the option to operate on this returning unleaded AVGAS qualities.

Lycoming claim to be prepared to discuss ethanol operations also in Europe, if a request comes forth. The Brazil experience is of the kind that it can be taken advantage of anywhere. So far, nor they or Kewit fuels have any activity in Europe.

4.3 The engine- the heart

Which body the engine is in or which fuel it carries is naturally not really the key issue. It is a matter of how well and engine can treat a fuel and how safe it is, how stabile the fuel composition is and what experiences have been made. "You can not really pull of to the side of the road if something goes wrong", someone said.

All engine manufacturers interviewed, claim that there is no technical problem adjusting the engine to any fuel. This statement is supported by the experiences obtained in vehicles on the road. Technology is solved, environmental benefits are defined but:

- o Fuel supply can not be secured
- o Economy cant be defined
- o Users that want a different fuel do not know of each other.

Beside the major engine suppliers, other manufacturers have attempted to move into market. Porsche manufactured a fuel injected engine from one of its car engines but did never introduce it. The market showed to be too small, as for Renault.

German Limbach has released one engine that can operate on any AVGAS fuel, it is liquid cooled and prepared for catalytic convertor as it has an altitude compensator and electronic injection. The use of electronics, reduce the fuel consumption and cuts operational expenses from the daily use of the aircraft. This is an 2,5 litre 100 hp boxer 4-cylinder engine.

Rotax is the largest engine manufacturer in Europe for small aircrafts with an annual production of 5.000 plus engines. Five two stroke engines for Ultra Light and one four stroke that probably can be considered climbing to the neighbourhood of not being Ultra Light anymore. The 912 is a 1200 cc 80 hp engine with electronic injection.

Newcomer

The General Aviation newcomer at this time is a Volvo return. An engine that originally operates in a Volvo 960 car has been tested, modified and tested again for five years and is now ready for release. In its car version, it has a catalyst, it has electronic control, fuel injection and six of the cars from 1992 operate in Los Angeles at South Coast Air Quality Management District (SCAQMD) on methanol. Volvo position is that what ever works with methanol also works with ethanol.

For test purposes, the engine has been put in a Piper PA 25 Pawnee, which originally has a 9 litre 2.700 rpm engine that produces 235 hp. The modern design of the Volvo, the very few adjustments from the car engine has made the engine unexpensive, spare parts are on-the-shelf products and the modern design has made that engine give as much pull power as the old fashion engine that was already in there. The Volvo is designed for 300.000 km trouble free driving even without regular service, whereas there is a new generation of thinking in this as well as in other European engines.

5. US Impact

5.1 Market

Europe has been dominated by US products as the market in the north Americas has been so lively. The European countries have struggled with different taxes and regulations, with too small markets in each country and no mutual regulatory body. The US designed Cessnas, the Pipers and other manufacturers have been able to sell the same products in Europe as in the US, whereas the sales there has been added value.

Design and technology with the US manufacturers may not be what Europe needs anymore. Environmental awareness, consideration for fuel efficiency and smaller engines with the same operational qualities is more like a customer need in Europe today when it comes to staying competitive.

Some corporate economic considerations

The US industry is known in Europe for a quick economic return on investment. This investigation does not cover any such research, but a quick return on investment may give good margins for a shorter period when the product in place is competitive. Competitors that "can not afford not to afford" development to meet market demand, will over-take those who go for quick return - for what ever reason that may be.

5.2 Legislation

There are fewer engine manufacturers than body manufacturers. The engine manufacturers all seem to have most of the fuel qualities available. They do also certify the engines according to what ever fuels may be possible to use.

It seems like the body manufacturer do not have all fuels available for certification and therefore certify to the conventional fuels. The certification that is taken into account when it comes to the final user is the final certification.

As US regulations dominate the certification process in Europe, and possibly in other areas in the world, a slight modification in the US regulations would open doors to new markets.

**AN END USER SHOULD BE ABLE TO USE ANY FUEL THAT
THE AIRCRAFT IS CERTIFIED TO, BE IT THE ENGINE- OR
THE BODY MANUFACTURERS CERTIFICATION.**

The following are two of the consequences such an adjustment would allow:

First:

Fuels that the engine manufacturers certify to could be the one that the end user chooses to activate and live by.

Second:

Alternative fuels certification would become less complicated, as only one (preferably the engine manufacturer) would need to certify.

As mentioned above, the US regulation make an impact in Europe, as there is no united European legislation, a change in the US will make an impact everywhere.

6. The market awareness

The AVGAS market is a small one, so small that the big Oil Corporations don't even have one man-year leadership on it. The pilots are enthusiasts that want to come home at night without a bad conscience for flying - except that it drains the family food- and vacation budget. There are no environmentalists and the Environmental Protection Agencies don't care because the consequences seem diffuse and the knowledge is too low on what really happens to the environment up there. The market is too small for the fiscal authorities to care - the General Aviation market lives life on its own, much as a submarket to something else- like for Rotax who do jet-ski engines, household tractor engines etc too.

Only noise is focused upon as that is a matter of survival. Much noise no flying - neighbours say.

On the professional side, the private enterprises mind their budget and there is no Government body that operates their own fleet that is big enough to mind.

Governments sometimes drive a market issue because somewhere there is someone in power to change for one or the other reason. That is not happening in Europe.

7 Conclusion

In conclusion it is sad to say that the alternative fuels does not play a role in European General Aviation, except for what is happening in Russia when it comes to LPG. On the other hand, the unleaded market has received a fair take off as a result of one enthusiastic and competent business man.

With no taxes on the fuel, no environmental debate to increase general awareness and no government programmes to stimulate the development of alternative fuels, there is nothing that drives Western Europe to move into alternative fuels. As a suggestion, the environmental debate could be stimulated by some research on environmental consequences at medium altitudes from aircraft pollution. This has been a guaranteed way of getting the industry moving in other markets.

A small market for a fairly high price hobby has driven the European engine manufacturers to develop much more efficient and smaller engines to replace and do the same work as big and not so modern designed engines do.

To promote the use of cleaner fuels, the US regulation could be adjusted to allow the end user to use any of the engine- or the body manufacturers certification for fuels. In the short run, this would allow a larger market for unleaded AVGAS. In the longer run, it may stimulate the use of other fuels if combined with Governmental R&D and environmental/energy legislation.

Expanding the Clean air Act Amendments or the EPACT may seem like utopia, but surely, there are links that could be used - especially from EPACT.

There is no likelihood that the European General Aviation market will create an alternative fuel development on its own.

WORLDWIDE ALTERNATIVE FUEL EXPERIENCES:
FRANCE

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CHIEF EDITOR
AVIATION PILOTE MAGAZINE (FRANCE)

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
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BAYLOR UNIVERSITY

Alternative Fuels in France

It is rather paradoxical, that France, a pioneer nation in a lot of aviation fields, is a late comer about this question of alternative fuels. But our country will not be a non-comer.

France has today the biggest aerospace industry in Europe with 100,000 workers, with a turnover of 20 billion dollars and a third in the world after USA and Russia, a some successful aircraft like Falcon Jets, Mirage, helicopters some good cooperations in Europe - Airbus, ATR - an air transport on his way to be de-regulated. We have also the 5th general aviation fleet in the world, and the third homebuilt fleet. There are 5 general aviation aircraft manufacturers; two piston engine manufactures, plus 3 established kit-makers.

At this time French aviation has no problem with fuel. The 7500 planes of general aviation fleet burn gently each year 10 millions hecto-liters (2.6 millions gallons) of Avgas without problem. The fear of an Avgas shortage present in the mid-seventies, no longer exists, as it is legal since 1985 to use car gasoline for most planes of the GA fleet. But petrol companies display strong commercial means to maintain their monopoly on aviation fuels.

Today there is no threat in France like "Clean Air Act" that would prohibit leaded aviation fuels. Ecologist organizations are politically weak. Although a new law, the "Air Law" will be discussed by the French parliament in December to enforce regulations against harmful emissions but this will apply only to land vehicles. It has been considered in France, according to German official report, that whole aviation moves in Western Europe accounts for only 3.2% of NOx emissions, and General Aviation part is only 0.02%. A so little share can hardly motivated a more stringent regulation.

AN INDIVIDUAL CHOICE

But if it is not legal concern, some pilots more sensitive about ecology, on an individual basis, have been actively searching possible alternative fuels. At the beginning of the 80s, a homebuilder modify the Lycoming engine of his two-seater plane to use liquid propane gas. His pattern had been used later by aircraft manufacturers, for training aircraft as well as tow plane for gliders, but this formula although technically successful got no commercial because of the heavy equipment needed. And pilots were not really prepared psychologically to fly with what is supposed to be a dangerous product.

USA, one more time in history showed us the way. At the Autumn 1989, we learnt a new possibility when Professor Shauck crossed the Atlantic with his Velocity running on ethanol, demonstrating there are other ways. Aviation & Pilote, our magazine, was the first to publish a story about him in the European technical press.

This rose a lot of interest, from French readers as well as readers from Africa or the Indian Ocean. We found that their main concern as pilots or operators is the price of the aviation gasoline.

In France, you pay an average 7 FF per liter, almost 5.5 dollars a gallon, this is 15% more than car gasoline. All pilots dream about a cheaper fuel.

Since 1987, in France there is a strong estatic support for all green fuels like bio-ethanol, bio-diesels; and ETBE. France, 1st world producer, 5th world cereal producer and 2nd cereal exporter, must reduce agricultural production according GATT and in the same time should

maintain jobs for country people. 10% of lands are set-aside. Of which 25% of 3,600 km² (889,576 acres) could be used for bio-fuels production. In 1994 1,300 km² (321,235 acres) have been used. It has been announced officially that 11 millions hl ethanol production can help to create or maintain 10 to 12,000 jobs. Just the volume of fuel needed by general aviation. French officials point out also that this will help France to reduce its petrol importations a good on both economic and strategic point of view. The national Agency for Energy saving claim that with 5% of bio-fuels in the 22.7 millions of m³, this could save the import of 580,000 tons of petrol equivalent. For all these good reasons the taxes on both ethanol and ETBE are less than car gasolines. \$4.3 millions dollars direct subsidy has been spent by the French government and European Union, pay a premium of 189 dollars per acre of set-aside land used for bio-fuel production. In that context France has become the largest biodiesel producers, which is used mixed with petrol diesel and for heating fuel.

In two towns of France, cities buses use an unleaded fuel with 5% ethanol. In Central France 1987 Moteurgar company equipped four city buses with 95% pure ethanol. They traveled more than 500,00 miles. An experiment was also conducted with Volkswagen car imported from Brazil, with a ethanol-fueled engine.

But nothing was tempted with planes. French authorities were reluctant to see an aircraft ins such experiments. They asked us can a plane engine afford safety almost pure ethanol when the French regulations allow only 5 to 10% ethanol in unleaded gasoline for cars?

To make a demonstration, we share the sponsorship of Max Shauck display at the Paris Air Show in 1993, the biggest air show in Europe, with his Pitts running on ethanol. Media, and a large public, saw then that ethanol can be used on planes. They think the aviation gasoline producers were not enough interested to launch a larger scale experiment with French planes. They think the aviation gasoline market is too small and not profitable enough. A gallon of alcohol for chemistry is worth 10 times a gallon of ethanol for aviation. We get also a lot of critics from aviation people, some were justified as the difficulties to start the engine, higher consumption, difficulties of stock and refueling, unavailability in most regions. Some were rather irrational; risks of corrosion, fire hazards, vapors. For the French environmental agency pure ethanol can be dangerous as it rejects "Aldehydes" polluting the air.

We face another objection from the ministry of Industry that found dangerous to include planes in field of experiments for biofuels.

ETBE, THE AFFORDABLE SOLUTION

For these reasons, ETBE is considered as a better bio-fuel option by French aviators. After Professor Shauck uses it for his second air display at the Paris Air Show in June this year, we had less media but more technical questions especially from homebuilders who can use, under their own responsibility, the fuel they want. They have been interested by the fact ETBE has closer performance compared to Avgas than ethanol and by the fact that our biggest national oil company, Elf, is also an ETBE producer since 1991. In 1993 Elf has used 340,000 hl for ETBE production.

So the conditions of a small-scale experiment slowly take place in France. But we still have to convince pilots, French civil aviation authority, that alternative fuels are safe, and can contribute to a brighter environmental future. For this purpose the experiments conducted in America by Professor Shauck are very important. Once a Cessna 152 will be certified to fly with ethanol or ETBE, we can expect many barriers, in France, to biofuels to go away.

FUEL COSTS

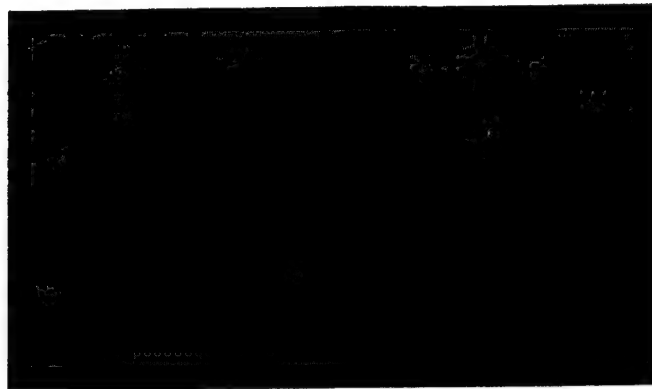
in France, prices in US Dollars per gallon

| | AVGAS | ETHANOL | SUPER | EUROSUP. 95 |
|--------------|-------|---------|-------|-------------|
| Production | 0,75 | 2,23 | 0,56 | 0,62 |
| Margin | 2,46 | 0,37 | 0,30 | 0,30 |
| TIPP (tax) | 1,47 | 0,02 | 2,76 | 2,51 |
| VAT (20,6%) | 0,69 | 0,54 | 0,74 | 0,71 |
| Retail price | 5,37 | 3,16 | 4,36 | 4,14 |

FLYING ACTIVITY

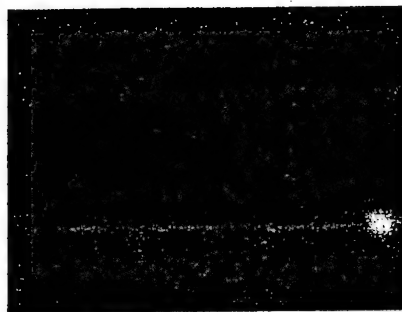
hours flown per year in France

TRANSPORT



1.750.000

**GENERAL
AVIATION**



1.000.000

**ARMED
FORCES**



500.000

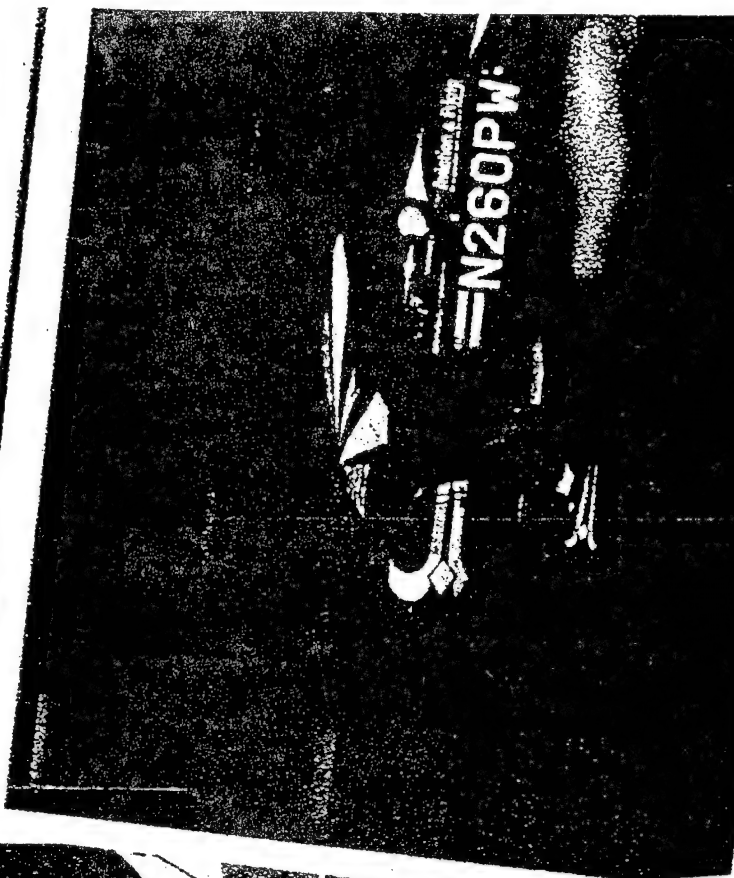
FUEL COSTS

in France, prices in Francs per liter

| | AVGAS | ETHANOL | SUPER | EUROSUP. 95 |
|--------------|-------------|-------------|-------------|-------------|
| Production | 0,99 | 2,95 | 0,74 | 0,82 |
| Margin | 3,26 | 0,50 | 0,40 | 0,40 |
| TIPP (tax) | 1,95 | 0,03 | 3,65 | 3,32 |
| VAT (20,6%) | 0,90 | 0,71 | 0,98 | 0,93 |
| Retail price | 7,10 | 4,18 | 5,77 | 5,47 |

Reportage

Aviation & Pilote NUM SPEC



Aéro-Forum

Vive Max Shauck !

Les articles concernant Max Shauck nous révèlent un personnage attachant et hors du commun. Il est le gérant de la pérennité d'une passion en anticipant l'application des mesures de protection de l'environnement. Plus que cela, il est certainement un fervent défenseur de ce dernier dans son ensemble. Je regrette que davantage de place dans la revue de juillet ne lui ait été réservée. J'adhère à une petite association de restauration d'anciens aéronefs et le combat que mène Max Shauck nous concernera dans un avenir plus ou moins proche, tant ce qui concerne de près ou de loin

par
de
supra

Le professeur Shauck a, une fois encore, frappé très fort en arrivant au salon du Bourget avec son fameux Pils aux couleurs texanes, carburant cette année à l'ETBE. — Une pre-

5-L'ETBE, UN NOUVEAU CARBURANT VERT AU BOURGET

Le retour de Max Shauck

Max Shauck, le pilote de l'ETBE, un avion à moteur à réaction, se fera entendre à l'occasion de la manifestation organisée par l'association d'anciens aéronefs et le combat que mène Max Shauck nous concernera dans un avenir plus ou moins proche, tant ce qui concerne de près ou de loin

N

FLYING ACTIVITY

hours flown per year in France

**ARMED
FORCES**



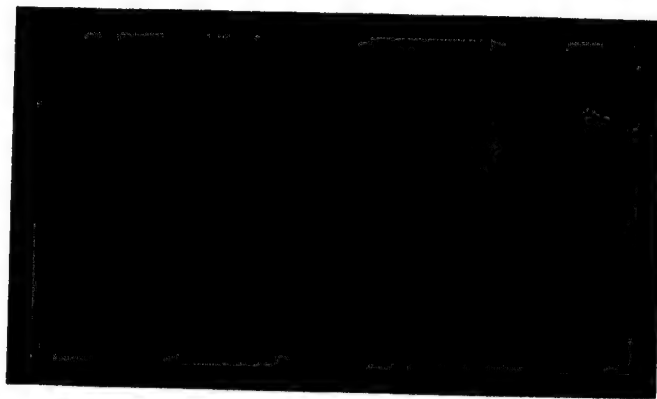
500.000

**GENERAL
AVIATION**



1.000.000

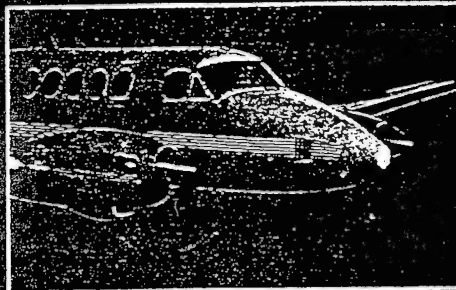
TRANSPORT



1.750.000

Aviation & Pilote

AIR NORMANDIE



SMALL IS BEAUTIFUL

**QUELS
CARBURANTS
POUR
DEMAIN ?**

**REPORTAGE
CHOC**

**EN VOL :
LE BAN-31 BIPLANE
DE MICHEL COLOMBAN**

**HERBERT LÉONARD :
LE CHANT DU YAK**

M 1062-263 - 35,00 F



N° 263 - DÉCEMBRE 1995. France: 35 FF - Belgique: 256 FB

Canada: 3,95 \$ CAN - Luxembourg: 245 FL - Suisse: 11 FS

QUEL CARBURANT AVION POUR L'AN 2000?

La première grande conférence internationale sur les carburants de l'aviation générale s'est tenue à l'université de Baylor, à Waco (Texas), du 2 au 4 novembre. Elle a permis un échange de points de vue entre divers officiels, chercheurs, organisations de pilotes, pétroliers, avionneurs et motoristes sur un sujet « chaud » : avec quel carburant volerons-nous quand l'Avgas « plombé » sera prohibé ?

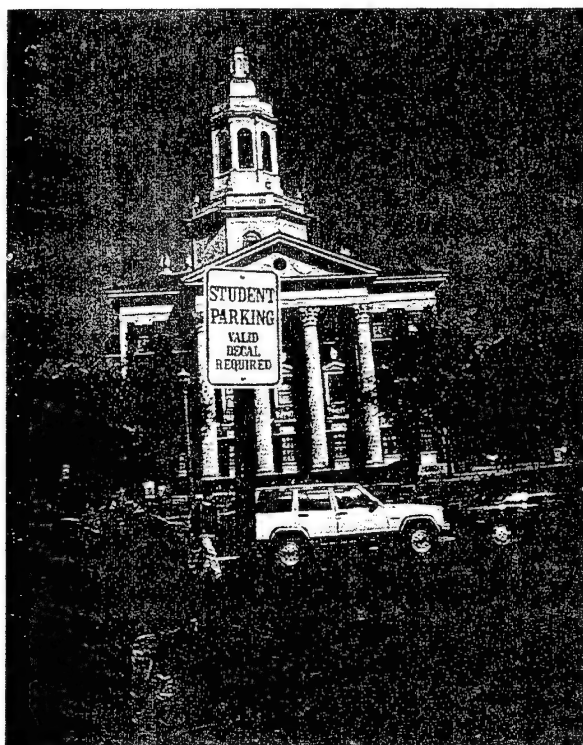
SUJET brûlant dans les années 70 alors que le monde entier s'inquiétait de la flambée du prix du pétrole et des disponibilités en Avgas, la question du carburant revient sur le devant de la scène.

Depuis le début de la présente décennie, les inquiétudes *environnementalistes* ont pris le relais des soucis de pénurie de pétrole. — Aux USA, notamment où depuis 1990, le Clean Air Act (Acte pour l'air propre) interdit aux automobilistes l'utilisation de carburant contenant du plomb.

Le bâtiment de direction de l'université de Baylor, à Waco, Texas, où s'est déroulée cette première conférence.

L'AOPA, représentant la majorité des pilotes privés américains, a obtenu que l'aviation ne soit pas concernée dans l'immédiat par cette mesure mais, comme le fait remarquer Doug McNair, chargé des affaires d'État au sein de l'AOPA : « L'agence américaine de protection de l'environnement (EPA) n'a sans doute pas dit son dernier mot. »

Autre motif d'évolution, le coût du carburant d'aviation aux USA.



S'il peut paraître encore dérisoire aux yeux des Européens (2 US \$ le gallon soit 2,50 FF le litre) et permet un prix de 150 FF à l'heure de vol sur Cessna 152, pour une majorité d'Américains c'est cher ! Le nombre d'élèves pilotes est tombé sous la barre des 100 000 l'an passé.

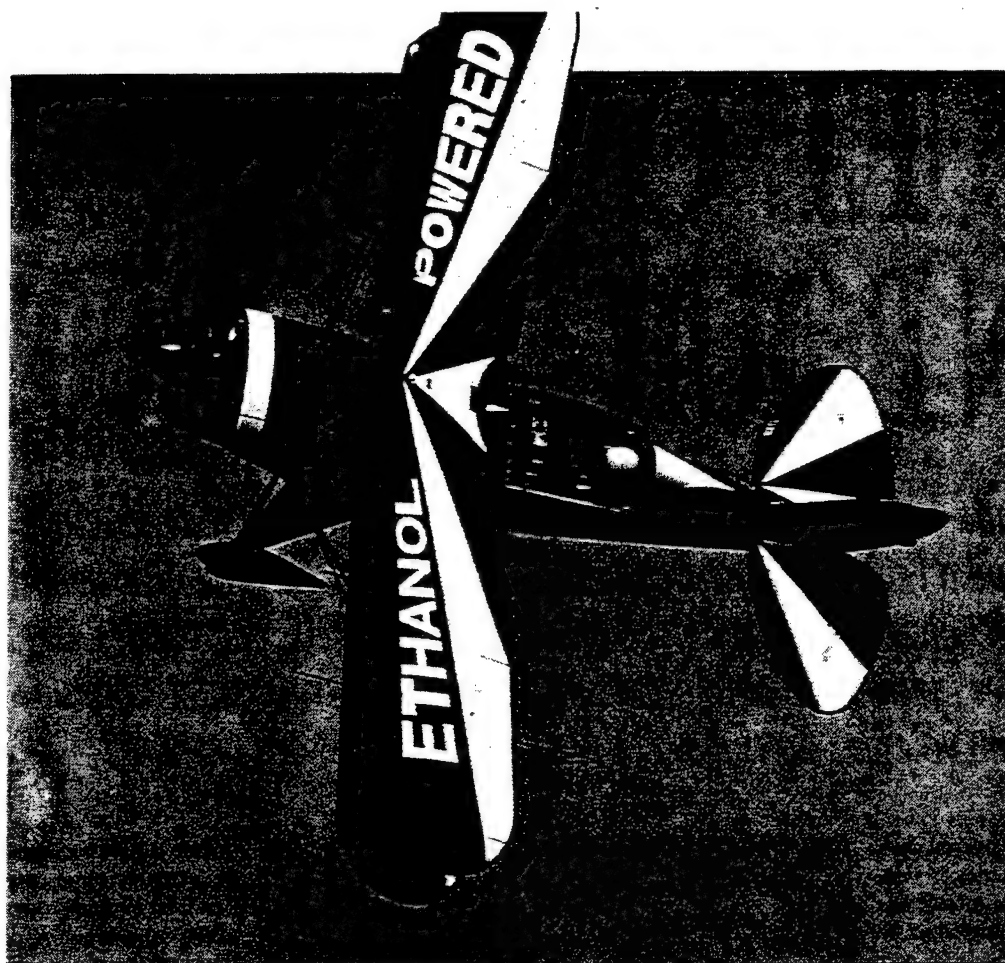
Aussi, cette « conférence interna-

tionale sur les carburants de remplacement pour l'aviation générale » organisée conjointement par l'université de Baylor, le ministère US de l'Énergie, l'Administration fédérale de l'Aviation (FAA), l'université technique du Texas, a été un véritable événement, attirant près de 200 spécialistes avec pour vedettes l'un des pionniers de l'espace, le cosmonaute Gordon Cooper Jr et Paul McCready, le père de nombreux appareils talentueux à propulsion musculaire et solaire.

Pour la première fois,

...ceux qui tiennent les commandes de l'Aviation générale aux États-Unis, évidemment fort conservateurs (avionneurs, pétroliers, administration), ont accepté de débattre avec ceux qui proposent d'autres solutions, plus ouverts aux solutions nouvelles.

Et Max Shauck, qui est bien évidemment l'instigateur et le maître d'œuvre de cette conférence, a mis



par
Philippe
DE SEGOVIA

*Photos Dan ISEMINER
(Vanguard), IRI, Ph. S.,
Jean-Louis NOËL.*

*Le Pitts S2B du
professeur Shauck voltige
à l'ETBE.*

— un peu — de côté son discours militant en faveur des énergies renouvelables, pour permettre à chaque point de vue de s'exprimer, faisant ainsi de ce forum une véritable réussite. Chaque auditeur était donc à même de tirer ses propres conclusions, même si les partisans des énergies renouvelables — dont les représentants d'associations agricoles américaines —, dominaient largement l'assemblée.

D'autres carburants

De la propulsion musculaire ou solaire développée par Paul Mac-Cready pour ses appareils qui ont traversé la Manche, jusqu'au Piper Super Cub du cosmonaute Gordon Cooper qui vole au méthanol en passant par les expériences de Max Shauck avec l'éthanol et l'ETBE, la plupart des énergies utilisées en aviation ont été décrites, excepté le kérosène dont la consommation est marginale en aviation générale.

Une nette tendance s'est dégagée en faveur de carburants «oxygénés»

comme l'éthanol (35 % d'oxygène), excluant le méthanol, carburant d'origine fossile, non renouvelable donc et surtout terriblement corrosif.

Cela tient d'abord à des raisons économiques : alors que l'Amérique importe 53 % de son pétrole, 19 états y produisent 50 millions d'hectolitres d'éthanol à partir de 450 millions de boisseaux de blé 100 % US (1). — De quoi faire voler la flotte entière de l'aviation générale.

En outre, l'éthanol bénéficie de fortes subventions, qui le placent sur le marché à un prix de 1,1 \$ US le gallon contre 2 \$ pour l'Avgas. Ces aides sont justifiées sans complexes les politiciens locaux :

« Une subvention, c'est la reconnaissance par l'État du bénéfice apporté par un produit. Nous croyons aux énergies du futur, surtout si ça peut créer des emplois au Texas ! ».

Sur le plan technique, les partisans des biocarburants notent que l'indice d'octane des «oxygénés» est comparable à celui de la 100 LL, voire plus élevé : 115 pour l'éthanol

et 111 pour l'ETBE. — À comparer avec les indices obtenus pour les carburants sans plomb proposés aux États-Unis : entre 82 et 96.

Les essais menés avec la plupart de ces carburants confirment leurs caractéristiques intéressantes et la simplicité d'adaptation des moteurs.

Le seul problème posé par l'éthanol reste son plus faible pouvoir calorifique (21 000 kj/l contre 32 000 pour l'Avgas), qui se traduit par une distance franchissable plus faible.

D'où l'intérêt suscité par l'ETBE, cet éther produit par craquage catalytique et dont les caractéristiques sont plus proches de la 100 LL (26 000 kj/l) tout en étant un biocarburant, au moins pour moitié.

Les diverses embûches actuelles

Pourquoi alors ces biocarburants ne sont-ils pas plus répandus ?

D'abord pour des problèmes de distribution : vous trouvez de l'Av-

(1) NDLR :
1 boisseau
= 36 litres.

Maquette d'un moteur 2 temps de 30 cv à combustion conçu pour fonctionner à l'éthanol.

En page opposée, les monoplaces Van's RV3 du Vanguard Squadron (ici, au-dessus de l'université de Baylor) assurent 25 meetings l'an.

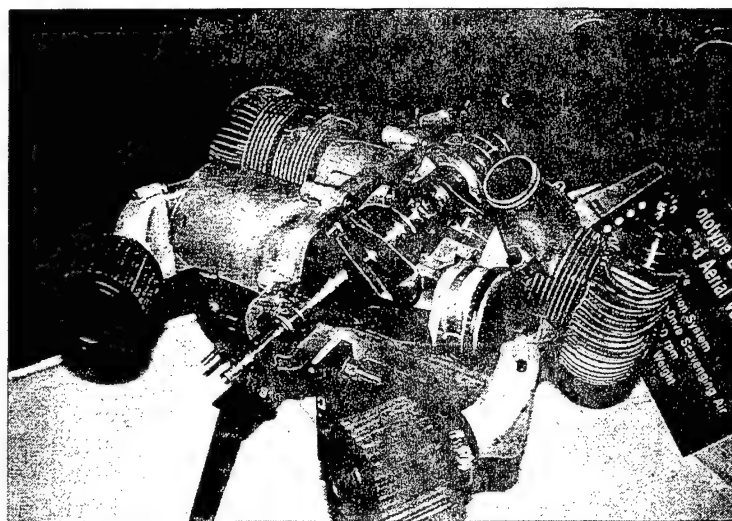
Ci-dessous, Max Shauck, promoteur infatigable des biocarburants.

gas sur tous les terrains, aux USA ; pour l'éthanol, il faut s'organiser. De surcroît, la marge des distributeurs est relativement étroite.

Les FBO (Fixed Based Operators) qui assurent l'accueil sur les terrains vivent surtout de l'Avgas qu'ils touchent à 0,5 \$ le gallon et revendent 2 \$. Sur l'éthanol, leur marge serait évidemment plus faible.

Ensuite, parce que jusqu'à présent seuls des appareils expérimentaux volent avec des biocarburants. Pour voler avec un avion ordinaire avec un autre carburant que l'Avgas, il faut obtenir un supplément à la certification (STC). La FAR 33, paragraphe 47 (2) stipule qu'après essais au banc, le moteur doit être démonté et inspecté pour prouver que toutes ses pièces sont demeurées conformes à la définition d'origine.

De plus, doivent être menées environ 150 h d'essais en vol pour démontrer que le moteur ne peut pas



C-152 et Pawnee bientôt certifiés

Un premier moteur a été certifié en 1989, le Lycoming IO-540, et le premier moteur à carburateur en 1991, un O-235. Mais le premier avion de série volant à l'éthanol, un Cessna 152 équipé du O-235, ne sera certifié que cette année grâce à une aide du Conseil de l'Enseignement supérieur du Texas (THECB). Au printemps prochain, il sera suivi par un Piper Pawnee équipé d'un IO-540, certification subventionnée par un consortium d'organisations de producteurs de céréales.

À partir du moment où des appareils aussi répandus utiliseront légalement de l'éthanol, on peut imaginer que davantage d'utilisateurs vont commencer à envisager sérieusement l'usage des biocarburants.

Notons au passage que l'éthanol n'est pas si nouveau que cela en aviation, puisque le premier avion supersonique, le Bell X1 de 1946 était propulsé par un mélange détonnant d'éthanol et d'oxygène liquide.

Des solutions à court terme

Au travers des interventions des orateurs, on appréhende très vite la situation aux États-Unis et son évolution, depuis l'époque héroïque où les avions volaient avec 40 octanes

avant de s'aligner lors de l'entrée en guerre de 1917 sur l'octane 70 des Européens, puis la mise au point en 1935 de la 100 LL que nous utilisons aujourd'hui.

Actuellement, la flotte américaine des 175 000 appareils à moteur à piston, effectue environ 24 millions d'heures de vol et brûle 302,2 millions de gallons d'Avgas. Demain, elle pourrait rester au sol si l'EPA interdisait tout carburant plombé ou décidait de faire monter le prix de l'Avgas à 10 \$ le baril, via les taxes.

L'AOPA (3), forte de ses 300 000 membres (pour une population d'un peu moins de 300 000 pilotes privés) s'est donc mise à la recherche active d'un carburant acceptable pour sa flotte. Doug McNair, son représentant, a dressé le portrait-robot du futur carburant d'aviation sans plomb.

Il doit pouvoir bénéficier d'une distribution mondiale, de caractéristiques techniques proches de l'Avgas (indice d'octane, sécurité, rapport énergie/densité, compatibilité matérielle) et conférer à l'avion des performances comparables en terme de distance franchissable et de puissance au décollage.

Estimant qu'il faut au moins dix ans pour obtenir la généralisation d'un carburant — dont deux années rien que pour sa certification, l'homme de l'AOPA a indiqué qu'il était urgent de disposer de ce carburant de remplacement. Pour toutes ces raisons, l'AOPA a soutenu la nouvelle norme de carburant sans plomb proposée par les pétroliers



(2) Normes qui concernent la certification d'un moteur.

prendre feu. Enfin, il faut obtenir une STC pour l'avion utilisant ce moteur. Tout ceci prend du temps et coûte cher comme le démontre les travaux de recherche et développement menés par Max Shauck depuis 13 ans à l'université de Baylor.

BP et Phillips avec indice d'octane 82, la 82 UL, dont la spécification devrait être adoptée ce mois-ci.

Bien sûr, cette norme ne répond pas à tous les critères exposés plus haut, notamment en terme de compatibilité avec les moteurs existants. Et elle ne fait pas l'unanimité, même chez les compagnies pétrolières. Un

dizaine d'années, d'abord avec plomb, puis sans plomb, sur un Cessna 150 qui totalise aujourd'hui 3 500 h d'essais.

Parce que l'EAA n'est pas sûre que les pétroliers vont continuer à produire un carburant d'aviation bon marché, elle préfère envisager le pire et sélectionner les carburants

plomb. Dans cette optique l'avionneur a développé ses propres bancs d'essais de carburant pour mesurer l'effet de la détonation sur le moteur TSIO-520 de 300 cv qui équipe ses C206 et sur le circuit carburant avec ses réservoirs du C 172.

De nombreux essais de carburant ont été effectués en collaboration



groupe de travail « Octane élevé » continue de travailler sur la question, qui pourrait inclure les biocarburants. En attendant, pour Doug McNair, « si le 82 UL n'est pas LA solution, c'est déjà UNE solution. »

De son côté,

...le représentant de l'EAA (4), Earl Lawrence, a expliqué pourquoi son association poursuivait une autre voie en testant intensivement les carburants automobiles depuis une

automobile ...les moins pénalisants.

Après ces exposés qui résumaient la position des principales associations de pilotes américains, la réponse de l'industrie — donnée en l'occurrence par Cesar Gonzales, responsable des projets au bureau d'études de Cessna, est plutôt rude: du genre « C'est la 82 UL ou rien ».

La position de Cessna

Depuis 1989, Cessna travaille sur la question des carburants sans

avec les pétroliers BP et Phillips. Verdict: les C 172 qui sortiront à partir de 1997 seront certifiés pour voler avec l'Avgas 82 UL.

Interrogé par des partisans un peu agressifs des biocarburants sur la mise à l'écart des autres solutions, l'homme de Cessna a répliqué que, pour faire redémarrer la production des monomoteurs avec un temps et avec des ressources limités, il fallait faire des choix. Il les résume ainsi: « Nous continuons à subir des poursuites judiciaires pour les monomo-

(3) AOPA: Aircraft Owners and Pilots Association, association des pilotes et propriétaires d'avions.

(4) EAA: Experimental Aircraft Association, association qui regroupe les constructeurs amateurs d'aéronefs nord-

teurs. Comme nous ne voulons courir aucun risque, nous avons opté pour un carburant actuel qui donne satisfaction». Toutefois, il n'est pas exclu que Cessna s'intéresse aux biocarburants, une fois passé le premier cap du retour de ses monomoteurs en production, d'ici cinq ans.

La position française

Mais Cessna a-t-il fait le bon choix sur le plan international ?

Représentant *Aviation & Pilote* invité (avec deux autres intervenants européens) à exposer la situation de la France vis-à-vis des carburants d'aviation, j'ai eu l'occasion d'apprendre à l'auditoire attentif de Waco que la France n'a pas encore appliqué de mesures antipollution pour les carburants aéronautiques et qu'il n'est pas sûr que la 82 UL y rencontre le succès. — L'aviation est, semble-t-il, considérée en haut lieu comme un pollueur marginal, de ce côté-ci de l'Atlantique.

Toutefois, si une législation européenne se faisait jour, nul doute que la France devrait s'y rallier. Et nous savons que nos pétroliers nationaux ont déjà dans leurs cartons des formules de carburant Aviaton sans plomb. En revanche, j'ai insisté dans notre exposé sur le prix de l'Avgas en France, qui incite déjà nombre de pilotes à voler au super automobile.

Dans cet ordre d'idée, l'ETBE s'il était produit en quantité comme additif pour l'essence sans plomb et largement subventionné, pourrait également intéresser notre population aéronautique.

Gordon Cooper Jr, le cosmonaute du film L'étoffe des héros, pionnier du programme Mercury en 1959 puis de Gemini en 1966, aujourd'hui défenseur de l'utilisation du méthanol sur avion léger.

Philippe de Segovia à la tribune : à la demande de Max Shauck, Aviation & Pilote avait été invité pour exprimer la position de la France et l'avancement des recherches de nos pétroliers en biocarburants.



En Italie,

...où l'Avgas est devenu rare, Mauro Furlan, pilote d'ATR 42-500 mais aussi ulmiste passionné, vole depuis de nombreuses années à l'éthanol. Mais il n'a guère pu convaincre d'autres adeptes, en raison des difficultés rencontrées à l'approvisionnement.



La situation actuelle en l'Europe

Mats Ekeland, consultant suédois, a résumé la situation en Europe : une consommation de 20 à 25 millions de gallons d'Avgas dans les pays où celle-ci est encore distribuée ; la Russie qui tourne à l'essence 91 ; certains pays d'Europe centrale qui volent avec de l'essence sans plomb 80 et la Suède, enfin, où commence à se répandre avec succès une essence Avion sans plomb, l'Avgas 91/96 UL, qui semble donner satisfaction.

Et d'indiquer aussi qu'une filiale de Volvo travaille sur un moteur 6 cylindres de 300 cv avionné, conçu pour tourner avec l'essence automobile sans plomb.

Selon M. Ekeland, ce moteur en cours d'essais pourrait débarquer sur le marché pour le tiers du prix d'un Lycoming de puissance équivalente. Mais, a-t-il précisé dans son exposé,

pratiquement aucune expérimentation n'a été menée en Europe avec des biocarburants.

Le Brésil,

...en revanche est un pionnier en la matière. Plinio Nastari, professeur d'économie et consultant pour le Conseil de l'Énergie mondial, a confirmé que 48,5 % des véhicules terrestres brésiliens consomment de l'éthanol, ce qui a pour effet de prolonger la vie de leurs moteurs. Reste à faire admettre l'éthanol par les milieux très conservateurs de l'Aviation générale brésilienne. Mais avec un prix de l'Avgas de 5 FF le litre, comparé à l'éthanol vendu 2 FF le litre, Plinio Nastari est persuadé que les choses vont bouger.

D'autant que le représentant de l'ONU, le Grec George Papadatos, vice-président du Conseil économique et social, est venu rappeler que l'ONU avait mis à l'ordre du jour le soutien aux pays qui développent des énergies moins polluantes et renouvelables.

Un show à l'éthanol

Enfin, la conférence s'est terminée par le premier show d'avions volant au biocarburant : la patrouille Vanguard Squadron et ses quatre RV 3 qui volent à l'éthanol depuis 1993, le Cessna 152 et le Piper Pawnee du Texas State Technical College utilisés pour les essais de certification de l'éthanol, le Pitts S 2B de Max Shauck qui vole à l'ETBE depuis cette année, sans oublier le Velocity, premier avion à avoir traversé l'Atlantique à l'éthanol.

Pour Max Shauck, l'objectif visé avec cette première conférence a été largement atteint : « Auparavant, j'entendais colporter que nous étions des dilettantes ; aujourd'hui, tous ont enfin pris conscience du fait que nous sommes des gens on ne peut plus sérieux ».

Et le « big chief » de Baylor de songer à des conférences régionales pour porter la bonne parole à travers les USA, à des conférences internationales en Europe ou au Brésil. Cette fois, le mouvement est lancé... Le progrès est en marche. ■

WHAT AVIATION FUEL FOR THE YEAR 2000 ?

THE FIRST BIG INTERNATIONAL CONFERENCE ON GENERAL AVIATION FUELS WAS HELD AT BAYLOR UNIVERSITY IN WACO, TEXAS, NOVEMBER 2,4. IT ALLOWED VARIOUS OFFICIALS, RESEARCHERS, PILOT ORGANIZATIONS, OIL COMPANIES, AIRCRAFT AND ENGINE MANUFACTURERS TO EXCHANGE IDEAS ABOUT A "HOT" QUESTION: WHAT FUEL WILL WE FLY ON WHEN LEADED AVIATION GASOLINE IS PHASED OUT?.

It was a hot subject in the 70s, when the whole world was upset by the increase of oil prices and the uncertain availability of aviation gasoline. Now the fuel issue is reviving and is once again in the forefront.

At the beginning of this decade, environmental concerns took over from concerns about the availability of oil as the reason to look into this issue. This was particularly the case in the USA, where, since 1990 the Clean Air Act had outlawed the use of leaded fuels in the automobile market.

AOPA, which represents a majority of the American private pilots, obtained a temporary waiver from this measure for aviation gasoline (av-gas). As Doug McNair, AOPA in charge of government matters, put it: "the Environmental Protection Agency (EPA) has not said its last word".

A further reason to develop an alternative fuel for aviation is economics. Even if the price of av-gas in the USA looks very cheap to Europeans (\$ 2 US/ Gallon are 2.50 FF/liter), for the majority of Americans it is high! The number of student pilots in the USA dropped under 100,000 last year.

The "International Conference on Alternative Aviation Fuels", jointly organized by Baylor University, the U.S. Department of Energy, the Federal

Aviation Administration (FAA), and the Texas State Technical College, was a real event, attracting about 200 specialists and distinguished names in aviation such as the astronaut Gordon Cooper, a space pioneer, and Paul Mac Cready, the father of many ingenious aircraft powered by human muscles and solar energy.

For the first time,

... those (seemingly very conservative) people, who are in charge of general aviation in the United States, (manufacturers, oil companies, administrators), have agreed to debate with those proposing other ideas and seem open to new solutions.

And Max Shauck, who was the organizer and master of ceremonies of the conference, put aside for a while his militant support of renewable energies to allow every point of view to be expressed, making this conference a real success. Each participant was able to draw his own conclusions, even if the partisans of renewable energies - among them the representatives of American agriculture associations were present in large numbers.

Other fuels

From the muscle or solar propulsion developed by Paul Mac Cready for his aircraft which cross the English channel, to the Piper Super Cub astronaut Gordon

Cooper flew on methanol and continuing on to the experiences of Max Shauck with ethanol and ETBE, most of the alternative fuels utilized in aviation were discussed.

There was a tendency throughout the debates to favor oxygenated fuels, such as ethanol (35% oxygen), over methanol, which is derived from fossil fuel, and is non renewable and very corrosive.

The main reasons for this preference are economics: while the United States imports 53% of its fuel, 19 states produce 1.5 billion of ethanol made from 600 million of bushels of corn, 100% made in USA. Enough to fuel the entire general aviation fleet.

Ethanol benefits from subsidies. It is available in the market for \$ 1.10 per gallon as opposed to av-gas at \$ 2.00 per gallon. These subsidies are well justified:

"A subsidy, is given by the state in recognition of the benefit brought in by a product. We believe in renewable energy, especially if it is able to create jobs in Texas!"

On the technical side, the promoters of biofuels stated that the octane number of the "oxygenates" is higher than 100 LLP: 115 for ethanol and 111 for ETBE. This is in comparison with the unleaded aviation gasolines proposed in the States at between 82 and 96 octane.

The tests on most of these fuels confirm their interesting characteristics and the simplicity of the engine modifications needed to use them.

The only problem encountered with ethanol is caused by its lower caloric content (21,000 kj/l against 32,000 for av-gas), which translates into reduced range.

Hence the interest in ETBE, which is an ether produced by catalytic cracking and which has characteristics closer to 100 LL (26,000 kj/l) while being still made from at least 1/2 biofuels.

The actual obstacles

So why aren't biofuels more widely used?

First, because of distribution problems: av-gas is available everywhere in the USA. Ethanol distribution needs to be organized. Furthermore, the profit for the distributor is relatively small.

FBOs (Fix Based Operators) that provide pilot services on the ground, make around \$0.50 profit from the sale of av-gas sold at \$ 2.00. For ethanol sales the margin could be lower.

Additionally, until now, only experimental aircraft could fly with biofuels. To fly with a certified aircraft with a fuel other than av-gas, it is necessary to obtain a supplementary type certificate (STC).

FAR part 33, states that before a bench test, the engine has to be disassembled and inspected to show compliance to the original configuration.

Moreover, 150 hours of tests have to be performed to assure that the engine will endure it. Finally, the airframe that goes with that engine has to also obtain an STC. All this takes time and costs a lot, as is demonstrated by the 13 years of research and development Max Shauck has done at Baylor University.

C-152 and Pawnee soon certified

In 1989, the Lycoming IO-540 was the first engine to be certified. And, in 1991, the O-235 was the first carbureted engine to be certified. But, it is not until this year that a Cessna 152 equipped with an O-235, will be the first aircraft certified on ethanol -- thanks to the help of the Texas Higher Education Coordinating Board (THECB). Next Spring, it will be followed by a Piper Pawnee equipped of an IO-540, certification of which has been financed by a consortium of grain producers.

Once these common aircraft can legally utilize ethanol, we can only imagine that more users will seriously consider biofuels.

Please note that ethanol is not new in aviation. The first supersonic aircraft, the Bell X1 in 1946, was powered by a mixture of ethanol and liquid oxygen.

The short term solutions

Through the presentations of the speakers, it was possible to quickly learn the situation in the USA and its history, from the heroic era of aircraft flying on 40 octane fuel before the entry of the U.S. into WWI in 1917 and the availability of 70 octane fuel in Europe, to the development in 1935 of the 100LL -- which we still utilize today.

Currently, the American fleet of 175,000 piston engine aircraft flies 24 million hours and consumes 302.2 million gallons of av-gas a year. Tomorrow, the fleet could be grounded if EPA outlaws all leaded gasolines or decides to increase the price of av-gas by \$ 10 a barrel through taxes.

AOPA, which has 300,000 members (for a population with little less than 300,000 private pilots), started a search for an acceptable fuel for its fleet. Doug McNair, its representative, presented his sketch of a future unleaded fuel.

It must have world wide distribution, and technical characteristics similar to those of the av-gas (octane number, safety, energy content, material compatibility) as well as provide the aircraft with comparable performances in terms of range and power on takeoff.

Estimating that it takes at least 10 years to obtain the general distribution of a fuel - and of those only two are for certification - the AOPA representative indicated that is urgent to find a fuel to replace aviation gasoline. For all these reasons, AOPA supports the adoption of the unleaded aviation fuel which is proposed by the oil

companies, BP and Phillips, with an octane index of 82. This 82 UL should be adopted this month.

It is clear that this formulation does not satisfy all the criteria specified above, especially in terms of compatibility with the existing engines. So, not everybody agrees with this formulation, not even the oil companies. A team is still working on the search for a "high octane" fuel -- which could include biofuels. In the meantime, as Doug McNair said "if the 82 UL is not the solution, it is at least A solution".

Meanwhile,

... the representative of the EAA, Earl Lawrence, explained the reason for his association's choosing to pursue another route by intensely testing automotive fuels for more than a dozen years, first with lead, later without it, on a Cessna 152 that totals, as of today, 3500 hours of testing.

Since the representatives of the EAA are not sure that the oil companies are going to continue to produce an aviation fuel at the same price level, anticipating the worst, they selected an automotive fuel, the least penalized.

After this presentation, which summarized the position of the main American pilot association, the position of industry was given by Cesar Gonzales, Senior Project Engineer of Advanced Designs at Cessna. His position was, "either 82 UL or nothing".

The position of Cessna

Since 1989, Cessna has been working on the issue of unleaded fuels. For this purpose the aircraft manufacture has developed its own test benches to measure the effects of detonation on the TSIO-520, 300 horsepower engine which is used in the C206 and on the fuel system of the Cessna 172.

Many fuel tests have been performed in cooperation with the oil companies BP

and Phillips. As a result, the C 172 that will be sold starting in 1997 will be certified to fly on av-gas 82 UL.

When asked by the proponents of biofuels about the possibilities of other solutions, the Cessna representative replied that in order to again produce a single engine aircraft in a short period of time and with limited resources, there are choices to be made. He summarized his view in this way, "We are continuing to contend with lawsuits for the single engine fleet. Since we do not want to take risks, we have opted for an existing fuel which is satisfactory." However, it is not impossible that Cessna will be interested in biofuels, once it gets some return on the production of its first round of single engine aircraft in 5 years.

The French situation

But did Cessna made the right choice on the international scheme?

Representing Aviation & Pilote, having been invited (with other European representatives) to talk about the situation in France in regards to the av-gas situation, I had the opportunity to tell to the attentive Waco audience that France does not yet apply pollution measures to aviation gasoline and that it is not clear that 82 UL will be successful. Aviation seems to be considered by the authorities on the other side of the Atlantic as a marginal polluter.

However, if European legislation is be enacted, there is no doubt that France will adopt it. And, we know that our national oil companies are already aware of unleaded gasoline formulations. Instead, during my presentation, I emphasized the issue of av-gas' prices in France, which already is causing pilots to look at automobile gasoline.

For this reason, if ETBE is going to be produced in quantity as additive for unleaded gasoline and if it will be subsidized, then it could be of great interest to our aviation population.

In Italy,

... aviation gasoline has became rare, said Mauro Furlan. ATR 42-500 pilot and ultralight enthusiast, who has been flying for many years on ethanol. But, other pilots did not join him yet, because it is currently difficult to find the fuel in Italy.

The current situation in Europe

Mats Ekeland, a Swedish consultant, summarized the European situation as follows: There is consumption of between 20 and 25 million gallons of av-gas in the countries where is still distributed. Russia is using 91 octane gasoline, some central European countries fly with an unleaded 80 octane gasoline and, lastly, Sweden has started to successfully use an unleaded gasoline, 91/96 UL, which seems to be satisfactory.

Additionally, a subsidiary of Volvo is working on a 6 cylinders engine with 300 horsepower, designed to run on unleaded gasoline.

According to Mr. Ekeland, this engine is still being tested and will come to the market at a third of the price of a Lycoming with the same horsepower. But, he added, there are practically no experimentation being conducted in Europe on Biofuels.

Brazil,

...on the other hand, is a pioneer in this matter. Plinio Nastari, professor of economics and consultant for the World Energy Council, confirmed that 48.5% of Brazilian vehicles use ethanol, which greatly prolongs engine life. What needs to be done is to have ethanol approved by the conservative Brazilian General Aviation cadre. And, with a price for av-gas of 5 FF per liter, compared with ethanol sold at 2 FF per liter, Plinio Nastari is convinced that things will change soon.

price for av-gas of 5 FF per liter, compared with ethanol sold at 2 FF per liter, Plinio Nastari is convinced that things will change soon.

Furthermore, the representative of the United Nations, the Greek George Papadatos, vice-president of the Economic and Social Council of the United Nations, came to remind the conference that the United Nations has made it a priority to support countries which develop cleaner and renewable energies.

An ethanol Airshow

The conference ended with the first show of biofuel powered aircraft: the Vanguard squadron, which is made up of four RV3s that have been flying on ethanol since 1993, along with the Cessna

152 from the Texas State Technical College and the Piper Pawnee (which are being used for the ethanol certification tests), the Pitts S2B of Max Shauck which flew on ETBE all this year, and not to be forgotten, the Velocity, the first aircraft to cross the Atlantic on ethanol.

For Max Shauck, the objectives of this first conference have been largely accomplished:

“In the past we were considered by some people to be dilettantes; today everybody is finally convinced that we are very very serious about this work.”

And the “big chief” of Baylor is thinking about holding regional conferences to spread the word through the USA, and about international conferences in Europe and Brazil. This time, the movement is launched... Progress is being made.

WORLDWIDE ALTERNATIVE FUEL EXPERIENCES:
ITALY

MAURO FURLAN
ITALIAN ULTRA-LIGHT ETHANOL PROJECT

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Italian Ultra-Light Ethanol Project
Mauro Furlan

Good day to you all! My name is Mauro Furlan. As far back as 1975, my friends, Pino Milito and Walter Mauri, and I foresaw, and were directly involved with, the birth of the now so-called Ultralights. We therefore consider ourselves pioneers in this branch of aviation in Europe or at least in Italy. Since then, we have developed and produced a wide variety of ultralights, which are well-known in many countries of Europe. Based on my previous experience, my part in these projects was to take care of test-flying and engine-testing, with alternative luck sometimes, but this experience provided me with considerable knowledge in two-stroke engines for light aviation.

In 1987, I had the chance to meet Max Shauck, who introduced me to alternative fuels - the idea was quite new then, at least for us over in Italy. So, after awhile, I got a little bit involved, I decided to see what we could do in Italy for our own sport of ultralights.

Italy now has about 15,000 ultralights, compared to just a few hundred general aviation aircraft. So, Italy has probably had the largest growth of ultralights of a single nation in the world. We are already penalized by a multitude of laws and restrictions, and we also feared an ecological backlash; for example, that we are using fuel just for fun, that we are polluting and so forth... So, I thought it would have been a good idea to see if we can at least have the sport of ultralights run clean.

I decided to see what I could do to modify my Wallaby, a two-seater trainer ultralight designed by Pino Milito, test-flown and developed by myself and well-known throughout Italy. Since I was operating an ultralight school at the time, I thought it would be a good idea to start and try to be a leader in drawing up a general line of conduct.

Max Shauck showed interest in my ideas and provided a 50-gallon drum of 50% ethanol and 50% methanol. Together, we went to the Rotax company in Austria, which is not too far from where I live, and we spoke to the directors there in the Engineering Department. They thought it might be quite feasible to use alcohol fuels in their engines, though they feared that some parts might corrode in contact with ethanol.

So, the first thing to do was to soak these parts in the alcohol mixture to see if they would actually corrode. The parts I soaked in the mixture were the parts that you normally find in the Bing carburetors, which are the most widely-used carburetors for Rotax around the world; the Rotax engine is used by millions for ultralights, homebuilts and experimentals around the world, so one of the points was to see if the float valve, which has a little tip made of rubber, would corrode or would resist and if we could use them, as well as the floats (made of plastic), and the pump membranes. After 800 hours soaking time, I saw no difference, so I went ahead and used off-the-shelf components.

A large part of my efforts were directed toward a situation where everybody can use alcohol fuels. There would have been no point in trying if a highly-specialized laboratory or research center would have been needed to modify these engines or engine parts for the use of alcohol; the person practicing the sport of Ultralight flying has to be able to go to the field and say, "Okay, today I'm going to fill up with ethanol;" maybe this person has to make a few simple adjustments - okay, that's acceptable, but if they have to start by dealing with timing, changing big parts, changing all the plumbing, tank and everything, there would be no way to push this new idea in our field of aviation. Therefore, I proceeded with a very simple idea in mind.. everybody can do it.

One of our worries was the fuels lines, the simple plastic tubes called Cavis Benz: these are very common in Europe. We were worried that they may become brittle, but they didn't; so, just go to the shop, buy them and fit them on. The cost is cheap; its what people use in motorbikes and cars.

So, instead of stainless steel tubing, we used a simple plastic tube. If you need information on where to buy these tubes, I'll be glad to let you know.

Once that was sorted out, we went on to the filters. And, I checked out a simple fuel filter which you can buy from the "Aircraft Spruce Specialty Catalog" - straight-forward, simple filter; plug it in and off you go. Actually, you can replace the inside filter because the container is made of glass and metal - its sort of a finger filter; its very simple, with no problems whatsoever.

Another very interesting aspect was the fuel tank. Years previously, in about 1978, we had made some fuel tanks for the first ultralights ever produced in Italy out of polyester fiberglass; the same cheap material used for boats, easy to obtain and purchase. We had problems with gasoline; after awhile it started slowly dissolving the container and releasing fibers and particles, which could clog the filters. So, in 1980, we developed a system to coat just the internal part of the fuel tanks (made this time of Deakane resin or epoxy resin, which is better), with simple paraffin, during the actual production phase of the fuel tank, and we had no further problems, neither with gas, nor with alcohol. Another very simple way is to use plastic canisters, the standard 20-liter plastic jugs/canisters used for drinkable liquids. So this is how we solved that problem.

Now, as already mentioned, we didn't want to have to change the engine timing because it's easy to change a jet needle or an idler jet, that's very simple, but you don't want to change the timing. So, after a few trials, we decided to go ahead and start on gasoline and then switch, once the engine is running, to straight alcohol. Anyway, we still had problems with idling, so we decided to replace the idler jet, and we increased its size by about 10 percent. Once we did that, we didn't need to start the engine on gas anymore, but it didn't reach the maximum R.P.M. So, we slightly modified the tuning of the carburetor.

The engine used then was a water-cooled Rotax 462, and we had to increase the main jet for the maximum R.P.M. by about 10 to 12 percent, according to the prop and reduction gear used. Anyway, these are simple adjustments. Well, now I can say that with a screwdriver and two jets in my pocket, within three minutes, I can make the conversion from gasoline to ethanol. I can land in a field, make the change, fill it up with ethanol, take off, land in another field, fill up with gas maybe, make a quick change. We had no problems up to this point. In fact, on January 31st, 1988, I made the world-first alcohol-powered ultralight flight in my Wallaby, and continued doing flights until I ran out of methanol-ethanol mixture.

Now, the problems in Italy is that it is very difficult to obtain ethanol, so I tried with the normal alcohol that you buy for disinfection, for cleaning, etc., which is 93% ethanol, with a denaturing agent, which sometimes is ETBE and sometimes they don't tell you what it is. Anyway, we went ahead and did some flights with this fuel. Also, at the same time, Walter Mauri was testing some engines for an ultralight altitude record, and we experimented with alcohol fuel in this context. We decided that he should take off on straight gasoline with a simple, off-the-factory engine without any modification, but his plane had two fuel tanks - one with gas and one with alcohol. As he climbed, he was to switch over very slowly to maintain R.P.M., because as altitude increases, the better alcohol performs, at least in two stroke engines, so Walter was to mix the fuel slowly with one valve in the cockpit between the two tanks, by closing one line and opening the line from the other tank, thereby passing slowly from full gas to full alcohol. Well, the test runs proved how simple it was, without the need to make any changes in the engine at all.

Then one day the German pilot, who had been flying for Walter, probably due to lack of communication (due to different languages) made a mistake, and just started straight on ethanol and took off straight, without noticing anything; he just had a lot of trouble starting it. So, we discovered by mistake that you can take an off-the-shelf engine and run it on alcohol, only that you will have problems with starting and idling.

What I want to do now is to see if I can put a Hellison carburetor on Rotax engines, a carburetor which can be adjusted by a turn of a screw, instead of by changing parts. But, that is in the future, because at the moment, it is impossible to obtain ethanol in Italy at a decent price; the taxes are extremely high (4.50 US\$ a liter), much more than on straight gasoline, even though Italy is one of the biggest producers of ethanol in Europe and is selling it, even to Brazil. So, we wonder what role the petrol companies may have in this.

One very important aspect of this research, which I have not yet mentioned, is the fact that the lubrication in the two-stroke engine comes with the fuel that goes into the tank; there is no oil sump. So, the fuel itself, as it's sucked into the engine, lubricates the rods and bearings and everything inside. So, we had to find an oil that can stay mixed and stable with alcohol. I tested about 10 motor oils, all easily found on the market, and one of them was suitable because after awhile, these oils separated from the alcohol. Then, I remembered that aircraft models run engines on alcohol and some sort of oil and that these little engines go up to 35, 36 thousand R.P.M.! Therefore, if they use an oil that can lubricate little gears that spin that fast, it has to be a good oil and obviously mixable with alcohols. I discovered that aircraft modellers use a highly-refined castor oil, which cost about half of the other petroleum-based oils, and the lubrication for our needs is even better. So, I ended up using a vegetable-derived oil with very high success, though you should run your engine on a regular basis and not let it sit too long. You cannot abandon the engine for one year without moving it, because this oil leaves a sort of sticky film inside. But, with normal use, it leaves less carbon residue and less dirt in the engine and the engine is cleaner and lasts longer. (The combustion smells a bit like frying potatoes, but that's okay.)

So, we reached two goals: one is that using a renewable fuel, like alcohol, in ultralights is possible and even easy. Two is that we don't even need petroleum-derived oils because we used vegetable oils.

We intend to continue this research in spite of the problems I've already mentioned. With my partners, I built a Loehle 5151 Mustang, which has a specially tuned Rotax 582 engine and a specially made tank that can run on all types of fuels. We chose this particular aircraft for its unique performance and appearance with the idea to fly airshow for the promotion of ethanol. We've encountered much skepticism along the way (especially in Italy), but we have always looked towards the future and we have continued experimenting with alcohol fuels in these new engine. I'm testing with rather strange things, too. For example, the alcohol used for disinfection (which is easier to obtain). I'm also running on gasoline and on Avgas with no problem. I will try to blend alcohol with biodiesel, in order to avoid using castor oil. Biodiesel itself should be a sufficient lubricant. Now, as soon as I am able to fit a Posa or a Hellison carburetor on, I will have even more data, but the main point is that anybody that runs a Rotax engine, for example skidoos, water jets or light aircraft can make the conversion with a flick of the fingers with off-the-shelf parts.

So, we can at least try to keep ultralights a clean sport. I would be interested in testing a couple of new engines, but at the moment it's a bit difficult to obtain them, due to high cost and availability problems. One new engine that is due to be tested shortly and which we expect will be one of the biggest breakthroughs, is the retractable engine in the Silent, the first glider in the world in the new Olympic category of under 115 kilos, 12-meter wing span, produced by Walter Mauri in Italy. The engine he developed for the Silent is a very light liquid-cooled engine (about 15 kilos, 28 hp, with a foldable propeller). With the incredible performance of this little airplane, we hope to be able to talk about 200 miles per gallon on ethanol. So that is our next goal, and we hope to be able to present this engine at the next Sun n' Fun in Lakeland or at the next major light aviation appointment.

I would like to take this opportunity to thank Max and Grazia Shauck for their help, friendship and encouragement.

ROLE OF THE UNITED NATIONS IN THE DEVELOPMENT OF
RENEWABLE SOURCES OF ENERGY

DR. GEORGE PAPADATOS
MINISTER-COUNCILOR OF ECOSOC
(ECONOMIC AND SOCIAL COUNCIL OF THE UNITED NATIONS)

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

My presentation will cover three areas :

- a) The response of the international community through the U.N. to the critical energy situation which prevailed in the 1970's. Main aspects of the Nairobi U.N conference on New and Renewable Sources of Energy (NRSE).
- b) Why the World Conference did not produce the expected results and give some of the reasons for the slow development of NRSE up to present.
- c) Some thoughts about the future of new and renewable energies.

A) Many governments in particularly those of oil importing countries have supported actively the holding in 1981 of the United Nations Conference on New and Renewable Sources of Energy (NRSE). It was attended by all members states of the United Nations. Its main scope was to promote reliance on a wider energy mix rather than on exclusive reliance on fossil fuels. It also promoted energy planning and conservation and addressed the critical energy situation of rural areas in developing countries. NRSE were seen as a main element in solving many problems. A Program of Action was adopted to be implemented by all countries according to their national plans and priorities and with the support of the international community. It contained five broad policy areas which were : Energy Assessment and Planing, research, development and demonstration ; transfer, adoption and application of mature technologies ; information flows; and education and training. One of the key ideas of the Program of Action was for NRSE to figure systematically in the energy plans and programs of many developing countries.

One of the outcomes of the Conference was the establishment of an Intergovernmental Committee responsible for the development and utilization of NRSE. The committee had a universal membership and its main function was to recommend policy guidelines for the entities within the United Nations system and to formulate and recommend action oriented plans and organs for carrying out the Program of Action. Its reports contained conclusions decisions and recommendations which were submitted to the General Assembly through the Economic and Social Council. These decisions and resolutions provided the basis for follow up by the organs, organisations and bodies of the United Nations system and for action by governments. Various entities of the United Nations initiated projects and programs as part of the implementations of the Nairobi Program of Action.

The Conference recognised that the implementation of the Program of Action would require a considerable amount of resources. There was a clear understanding that the magnitude of financial needs would be significant. It was also understood that each country would bear the major responsibility for developing its own new and renewable resources of energy programs, that the developing countries would need international financial support for their national efforts,

both public and private, from the developed countries, international financial institutions and other international organizations.

The program established no fixed target for investment requirements of NRSE in developing countries. However, the World Bank and UNDP undertook a joint study to estimate the financial needs for supporting actions and pre-investment activities in developing countries. The study produced a rough estimate of 14.2 billion dollars for the period 1982-1992 at 1982 prices. Of that amount 72% was for hydro power and geothermal energy, and the balance of 28% and balance of other new and renewable sources of energy.

The United Nations secretariat also produced some rough estimates in the early 80's according to which a total investment of 420 billion dollars will be required for total investment requirements in an NRSE in developing countries for the period 1982-2000. The study drew the conclusion that despite such heavy investment requirements the energy gap of energy-importing countries will still expected to continue to increase.

B) The dramatic events which led to the global energy situation and to the NRSE Conference of 1991 did not persist in later years. Drastic changes occurred with an unfavorable impact on the implementation of the program of action. For example energy programs and policies which were initiated world-wide under conditions of high world prices and reduced economic growth rates led to diminished energy demand and a considerable decline in oil consumption which was more pronounced in the developed market economies. The excess oil supplies and the sharp decline in oil had a far reaching impact on the global scene. Support for energy alternatives was reduced discouraging efficiency efforts reducing the trends towards self reliance and again raising dependence on fossil fuels, particularly petroleum. The overall policy environment during the latter part of the 80s was unfavorable to the promotion of NRSE. The long term approach emphasised in the Nairobi Program of Action was overlooked.

Energy pricing policies have had a decisive bearing on the implementation of the Program of Action. These policies did not take into account all relevant costs, I mean externalities related with conventional sources of energy and as a result NRSE were placed at a competitive disadvantage. Policies in NRSE of energy projects in a number of countries have been ineffective due to inadequate incentives and in the case of producers to limited access to credit finances or lease finance.

Today, more than 14 years after the adoption of the Nairobi Programme of Action, most of the increases in energy consumption are being met by conventional fuels rather than by new and renewable sources of energy. The current share of renewable energy in total energy consumption is estimated at 17.7 per cent.

Financing and investments

Public budgets for research, development and demonstration in renewable energies in the Western countries - despite a revival of activities in some countries in recent years - declined sharply, from \$1,665 million in 1980 to \$487 million in 1990, at 1990 prices - a fall of about 70 per cent. The decline was more pronounced in the areas of mature technologies (such as solar heating and geothermal energy) and in technologies with little prospect for use in the near future (e.g., ocean energy).

Similar sharp declines have taken place in new and renewable sources of energy expenditures in developing countries partly owing to the keen competition from conventional sources of energy and partly to severe shortages of capital, from both internal and external sources, for all types of investment programmes and projects. In general, despite the considerable efforts made, the financing resources allocated to new and renewable sources of energy programmes during the past decade were so meagre that they could not make a significant impact on the economic of developing countries, at either the national or the local levels.

Methods and sources of financing

The financing of programmes and projects on new and renewable sources of energy in many developing countries in the past has been carried out largely through external funding. In domestic financing, government budget allocations have played the most important role, either directly or through banking and other credit systems. The participation of the private sector appears to have been rather limited. External financing has come from both bilateral and multilateral sources and, among the latter, intergovernmental organizations and the United Nations system, especially the World Bank group and the regional development banks, have provided the bulk of financing. In bilateral financing, the bulk has come through official development assistance (ODA). Some funding has also come from private sources.

Available data show that, of the reported \$36 billion that was funded for new and renewable sources of energy between 1980 and 1986, the largest share, about 26 per cent, came from domestic resources; of the balance, the United Nations system accounted for 25 per cent,

intergovernmental organizations 16 per cent, bilateral sources 18 per cent. Hydropower accounted for about 75 per cent of the expenditures, followed by biomass energy conservation, geothermal energy, energy planning, solar and wind energies and others.

The United Nations system has provided substantial amounts of financing for new and renewable sources of energy projects in developing countries. In recent years, however, the volume of such financing has declined, particularly if the contributions are calculated in real terms. Even the World Bank group, which appears to have maintained the high level of its commitment and contribution (about 70 per cent) has gone to hydropower projects and most of the balance to fuelwood.

In concluding, financing for new and renewable sources of energy programmes and projects, despite the successes achieved in the early part of the 1980s, has declined in recent years. In the developed market economies, public expenditures for research, development and demonstration activities have been scaled down, and private involvement in new and renewable sources of energy investments has been greatly curtailed. In the developing countries, with the exception of a few countries, there have been similar trends.

Several new and renewable sources of energy technologies were expected to reach the stage of commercial readiness and become marketable in the 1980s. Anticipating large market potential for such technologies in developing countries, bilateral donors and multilateral agencies supported projects involving supply of new and renewable sources of energy devices and systems for demonstration and field testing. Entrepreneurs hastily looked for marketing opportunities without going through the adaptive process for technology transfer. Project activities turned out to be isolated. Many projects were unable to fulfil their objectives because of a rapidly changing technology and market environment. The commercialization effort received a set-back owing to budgetary cutbacks in most developed countries for demonstration and commercialization projects. In the past five years, there has been a reduction in the number of enterprises engaged in new and renewable sources of energy technologies. The withdrawal of various tax rebates and concessions also had an adverse impact on the growth of new and renewable sources of energy industries.

Techno-economic factors

Several new and renewable sources of energy technologies have reached the stage of "technical readiness"; however, the initial high cost of new and renewable sources of energy technologies has been the main deterrent to the wider utilization of those technologies. The economic viability of such technologies seemed attractive enough to be considered as potential oil substitutes, particularly when oil prices were relatively high; however, the drop in oil prices in 1986 and the softer conditions that prevailed thereafter, except during the Gulf War, affected the

economic viability of several new and renewable sources of energy technologies. Those factors, together with the slow-down in economic growth of many countries, both developed and developing, adversely affected renewable energy development.

Manufacturing capabilities and possibilities

The establishment and development of capacity at the national level for the manufacture, operation, maintenance, marketing and management of equipment and spare parts related to the use of new and renewable sources of energy were identified in the Nairobi Programme of Action as a priority area for action. International cooperation was expected to assist in facilitating the transfer and adaptation of technology which would enable manufacturing to be undertaken locally. In seeking to achieve these goals, developing countries face several obstacles and constraints. First, they face the uncertainties associated with the rapidly evolving nature of new and renewable sources of energy technologies and the broad range of choices - from solar-thermal, electric and photovoltaic systems and wind electric systems to wood stoves, biogas plants, biomass gasifiers and so on. Secondly, they face the problem of having to adapt those technologies to local conditions. They must also be prepared to provide infrastructure, trained workers, testing and standardization facilities, and marketing and service capabilities.

The capability to manufacture new and renewable sources of energy, equipment varies from country to country. Major weaknesses exist in the areas of service and maintenance, marketing and management of equipment for decentralized applications. The less industrialized countries need assistance in order to enhance prospects for manufacturing.

The choice of technology and the scale of manufacturing are important considerations in ensuring successful manufacturing activities in developing countries. They need to have access to the tools and techniques of technology assessment used in the developed countries, not only to enhance their capability to enter into technology agreements but also to make more informed judgements about joint ventures with respect to such areas as appropriateness of technology, research and development requirements for adaptation and improvement, unpackaging of technology, quality control and standardization to suit local conditions.

Only a few joint ventures have materialized, in spite of the vast scope that exists. For example, active and passive heating technologies, biomass-based technologies and wind electricity generation are already widely used in the developed countries: Japan uses 5 million solar water heaters; and the technology is well established in Australia, Israel, Italy and the United States. Similarly, photovoltaic technology, devices and systems hold many inhibiting factors need to be addressed, such as the non-availability of specialized raw materials, infrastructural bottlenecks, poor research and development back-up and poor marketing and service capability.

C) In June 1992 the UN Conference on Environment and Development took place known as the Rio Conference. In the presence of over 120 heads of States and Prime Ministers the challenge of achieving worldwide sustainable development was the order of the day. Agenda 21 adopted by the Rio Conference calls "for new policies or programs, as appropriate, to increase the contribution of environmentally safe and sound and cost effective energy systems, particularly new and renewable ones, through less polluting and more efficient energy, production, transmission distribution and use".

The outlook for renewables is auspicious for meeting growing demand associated with an expanding world economy. Renewable systems have benefited from recent development in electronics, biotechnology and material sciences. Technology will be a major defecting factor in bringing renewables to the market place in competitive terms. However a transition to renewables will not occur at the pace envisaged if existing market conditions remain the same. New policy initializers are required geared to encourage innovation and investment in renewable technologies.

It seems that the scenaria of high energy price trends which led to heightened concerns about the adequacy of energy resources in meeting increases in energy demand did not materialize. Forecasts of \$100 barrel of oil were then not uncommon. Now after Rio the emphasis seem to be an environmental degradation which is partly caused by the increasing consumption of fossil fuels. The fear of climate change is particularly prevalent. There is greater awareness of enviromental costs but cost comparisons between fossil fuels and NRSE are difficult.

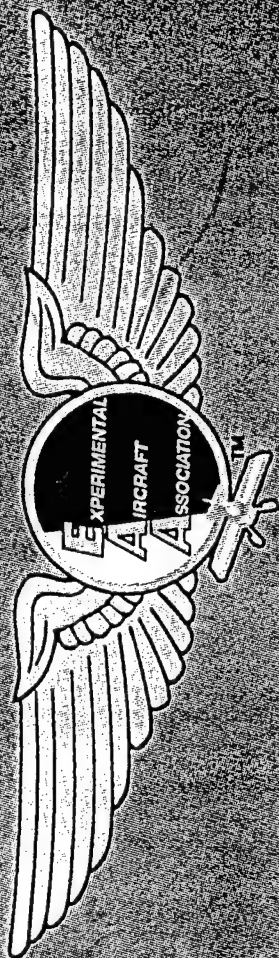
Future energy scenarios and projectives on NRSE are often based on assumptions which include optimistic technological forecasts and foresee a rapid reduction in costs which may not happen.

Moreover, either explicit or implicit assumptions of governmental subsidies and/or massive government supported research development programs are incorporated into such scenarios at a time when the world is moving toward free market economies with less involvement in government efforts.

**WORLDWIDE ALTERNATIVE FUEL EXPERIENCES:
THE EXPERIMENTAL AIRCRAFT ASSOCIATION**

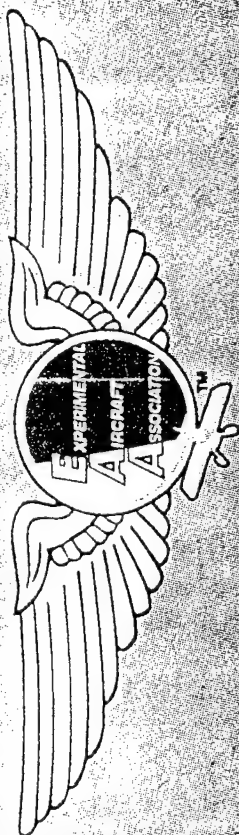
**EARL LAWRENCE
GOVERNMENT PROGRAM SPECIALIST
EXPERIMENTAL AIRCRAFT ASSOCIATION**

**FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY**

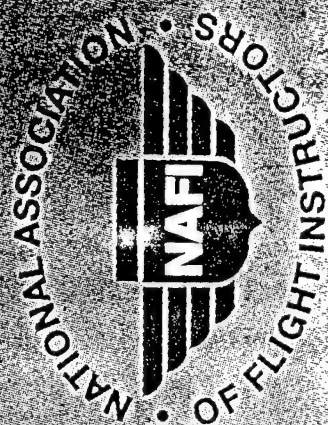
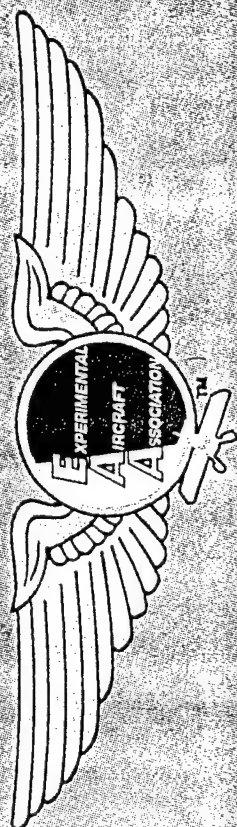


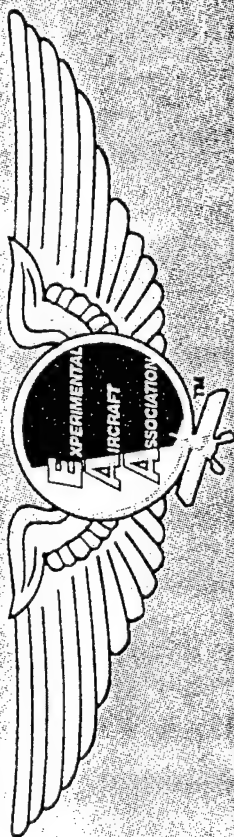
THE EXPERIMENTAL AIRCRAFT ASSOCIATION'S

ALTERNATIVE FUEL EXPERIENCES

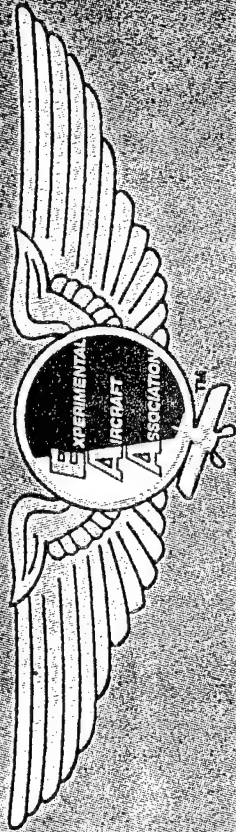


- **EAA HAS TEST FLOWN AIRCRAFT WITH**
Unleaded Automobile Gasoline
Oxygenated Automobile Gasoline
- **EAA HAS CONDUCTED MATERIAL COMPATIBILITY TESTING WITH**
Methyltertiarybutyl-ether (MTBE)
Methyltetrahydrofuran (MTHF)
Ethyltertiarybutyl-ether (ETBE)
Tertiaryanlylmethyl-ether (TAME)
Ethanol (ETOH)
Mixtures of MTBE and ETOH

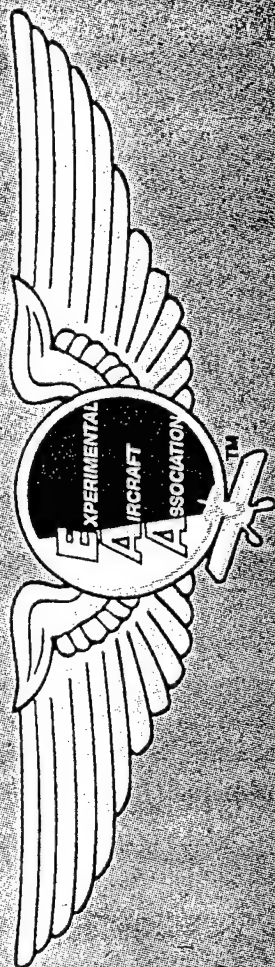




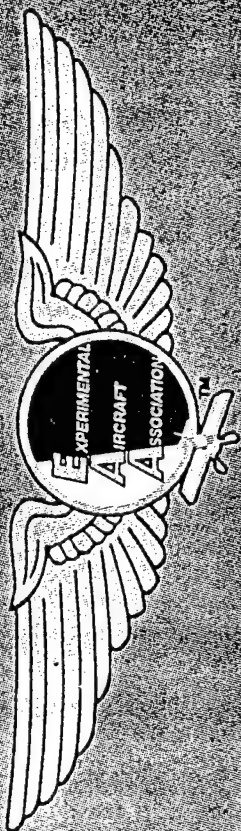
WHAT IS EAA'S INVOLVEMENT IN ALTERNATIVE FUEL?



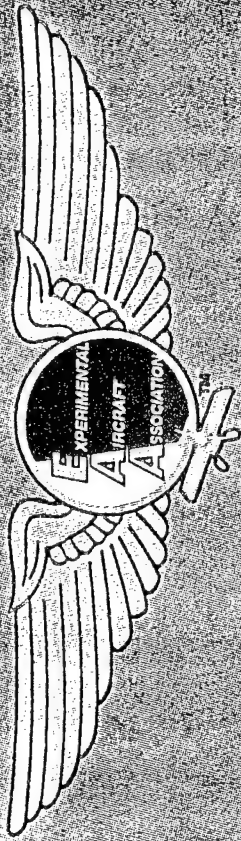
-
- EAA is involved in alternative aviation fuels because we believe they will be necessary for the future of Sport Aviation
 - EAA's goal in its alternative fuels programs has been to utilize the largest pool of gasoline available, thereby giving the lowest cost and most environmentally sound fuel.



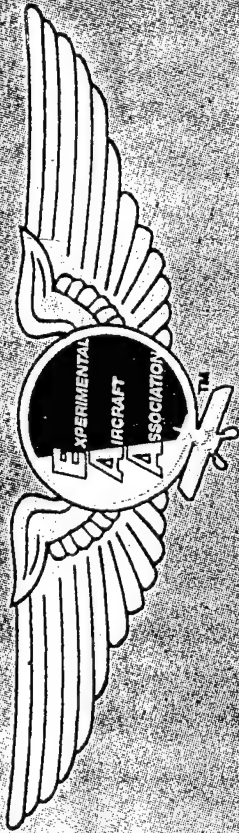
THE HISTORY OF EAA'S STC PROGRAM



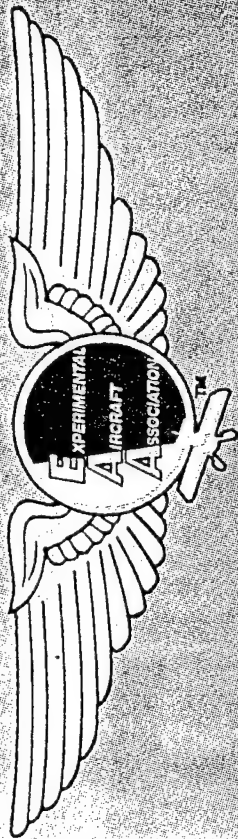
-
- **EAA started research into the certification of unleaded automobile fuels in the mid 1970's, with the flight testing of several experimental certificated aircraft with automobile fuel.**



-
- The first challenge EAA had to overcome was an FAA Washington moratorium against the FAA accepting any application to certificate an automobile fuel.
 - After a great deal of work, EAA was able to convince the FAA to allow EAA to start a formal certification test program.

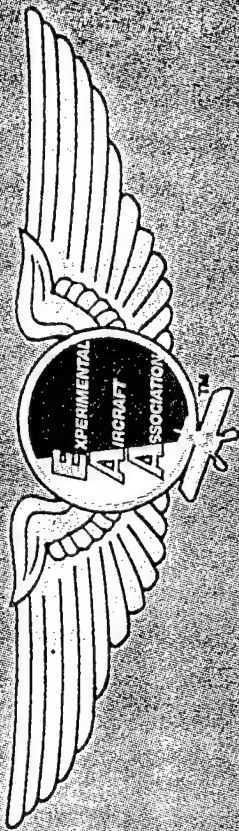


-
- In all of EAA's tests, no modification of the fuel systems or engines were necessary with the exception of instrumentation.
 - Automobile fuel use in aircraft with an EAA STC is "Transparent" to the aircraft. No modifications to the aircraft are required.

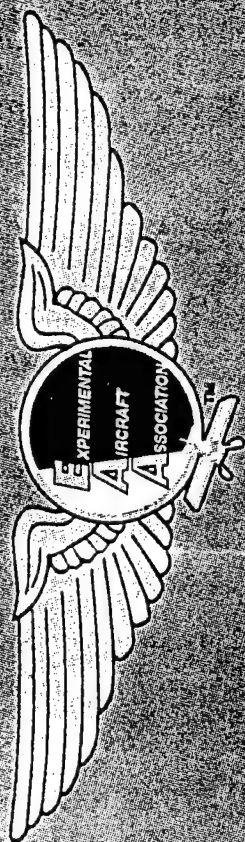


● Thirty measurements were recorded every 15 seconds

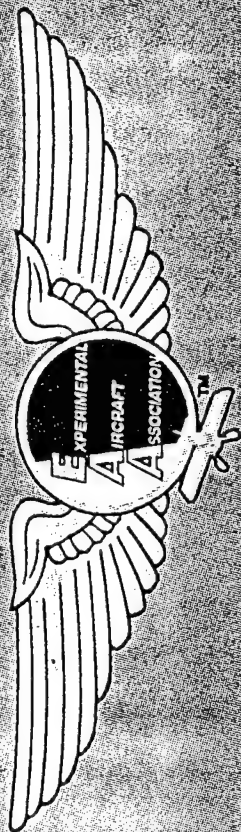
| | |
|------------------------|------------------------------------|
| INDICATED ALT | INTAKE MANIFOLD TEMPERATURE |
| PRESSURE ALT | THROTTLE POSITION |
| DENSITY ALT | EXHAUST GAS TEMPERATURE #1,2,3,4 |
| AIR SPEED | CYLINDERS |
| OUTSIDE AIR TEMP | ENGINE COMPARTMENT TEMPERATURE |
| ALTIMETER SETTING | CARBURETOR BOWL TEMPERATURE |
| VERTICAL SPEED | CABIN TEMPERATURE |
| OIL TEMPERATURE | CYLINDER HEAD TEMPERATURE #1,2,3,4 |
| CYLINDERS | FUEL FLOW |
| CARBURETOR INTAKE TEMP | TIME |
| MANIFOLD PRESSURE | LEFT FUEL TANK TEMPERATURE |
| | RIGHT FUEL TANK TEMPERATURE |



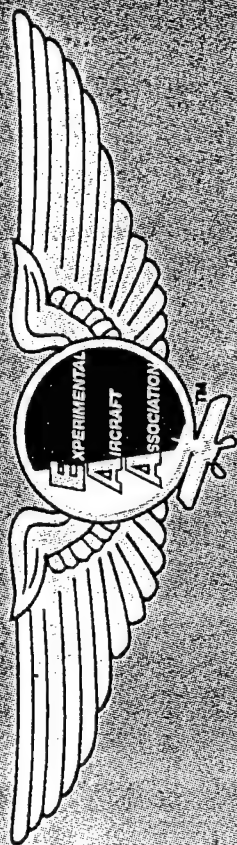
-
- Tested to altitudes up to 14,000 feet
 - Tested at OAT temperatures between -10°F and 101°F
 - Tested with fuel tank temperatures as high as 135°F
 - Tested with fuel with vapor pressures from 8psi to 16psi
 - Flown over 500 hours the first year of testing
 - Flown over 720 hours for the initial test program



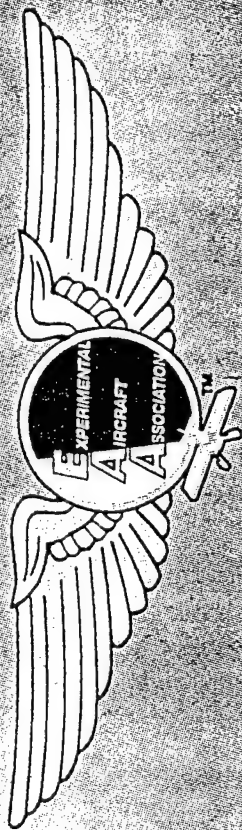
- **The University of Michigan was contracted to produce two worse case fuel samples at both ends of the scale of the automotive gasoline specification ASTM D-439**
- **Both fuels were flown in the C-150 without any complications**



- The aircraft were transported to Arizona for hot weather testing
- Specially formulated fuel with a Reid vapor pressure of 17 was transported and held in a refrigerated truck
- All flights with this fuel were conducted in OAT's in excess of 100° F

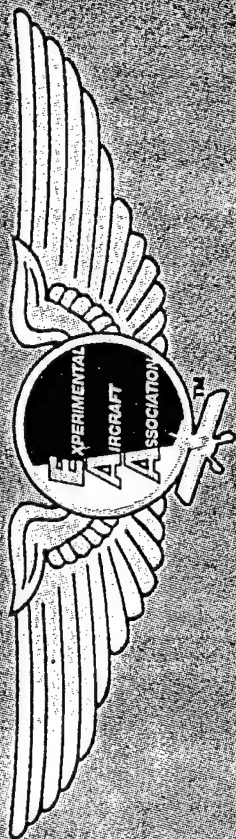


-
- **MTBE has been independently tested by the FAA**
 - **Gasoline with MTBE has been approved for use by the FAA in aircraft holding an automobile gasoline STC**
 - **EAA and Petersen Aviation have petitioned for FAA approval of gasoline with ETBE**

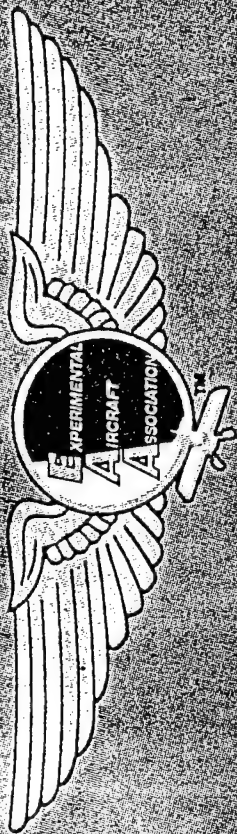


CONTINUED RESEARCH

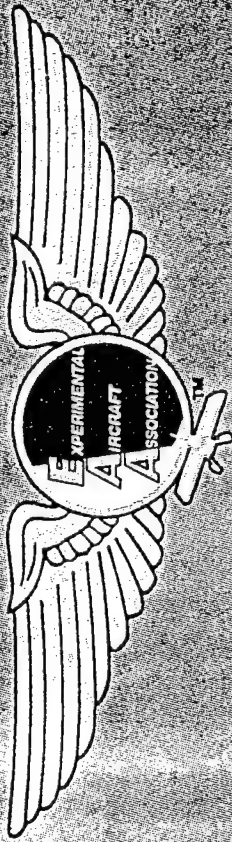
- EAA has continued its flight testing to include oxygenates
- Completed over 200 hours of flight testing on MTBE
- Completed over 100 hours of flight testing on ETBE
- Concentrations of up to 20% by volume have been tested of both MTBE and ETBE
- Small amounts of ETOH have been included to reflect the possible mixture of ethonal in with ETBE and or MTBE



-
- **A total of over 3,000 hours of flight testing was performed for EAA's original STC approvals**
 - **As of today EAA has accumulated approximately 5,000 hours of flight testing on various gasoline formulations**



- Today over 70% of the piston powered aircraft fleet is eligible for an automobile fuel STC.
- Over 30,000 aircraft are currently operating on automobile fuel consuming an estimated 20,000,000 gallons of fuel a year.
- There has been over 13 years of legal automobile gasoline use in standard category aircraft.



-
- **No significant problems have been shown with use of automobile gasoline in aircraft**
 - **A review of FAA fuel related accident reports from 1986 to 1993 show a higher incident of fuel related problems with 100 LL than with automobile gasoline**

MATERIALS COMPATIBILITY & OXYGENATED AUTO GAS - 100LL AVIATION GASOLINE

To:
Mr. Harry Zeisloft
EAA Aviation Foundation, Inc.

Submitted By:
John J. Thomas, Ph.D., Research Professor, Director
Steven E. Adams, Research Engineer
Erik E. Gordon, Research Engineer

Florida Institute of Technology
Department of Biological Sciences
Bio-Energy and Technology Laboratory
150 W. University Blvd.
Melbourne, FL 32901-6988

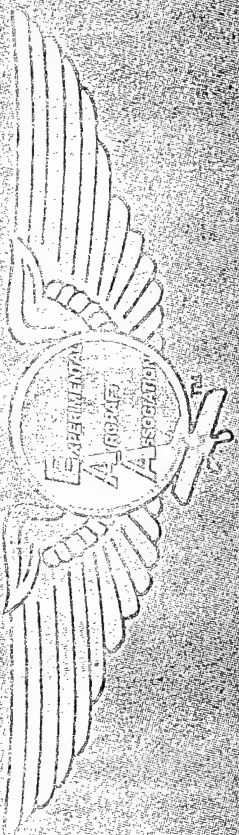
February 20, 1995

TABLE 1. FUEL BLENDS USED DURING PHASE 1 TESTING.

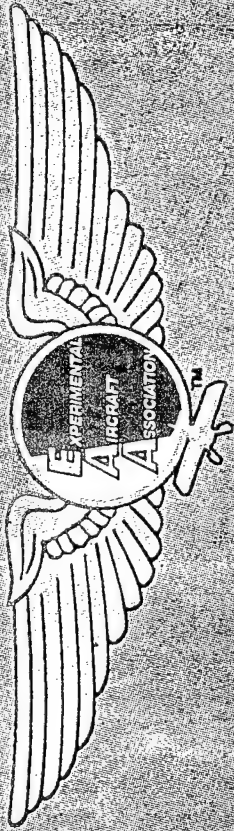
1. Reference fuel, 100LL aviation gasoline.
2. Unleaded regular gasoline, 87 AKI.
3. Unleaded regular gasoline, 87 AKI, with 5% ETOH/4.22% MTBE - 2.7% Oxygen by weight.
4. Unleaded regular gasoline, 87 AKI, with 2.17% ETOH/10% MTBE- 2.7% Oxygen by weight.
5. Unleaded regular gasoline, 87 AKI, with 29% MTBE - 2.7% Oxygen by weight
6. Unleaded regular gasoline, 87 AKI with 14.4% MTBE - 2.7% Oxygen by weight.
7. Unleaded regular gasoline, 87 AKI, with 16.7% ETBE - 2.7% Oxygen by weight.
8. Unleaded regular gasoline, 87 AKI, with 16.1% TAME - 2.7% Oxygen by weight.
9. Unleaded regular gasoline, 87 AKI, with 7.06% ETOH - 2.7% Oxygen by weight.
10. Unleaded premium gasoline, 93 AKI, with 14.6% MTBE - 2.7% Oxygen by weight.
11. Unleaded premium gasoline, 93 AKI, with 16.8% ETBE - 2.7% Oxygen by weight.
12. Unleaded premium gasoline, 93 AKI, with 16.2% TAME - 2.7% Oxygen by weight.
13. Unleaded premium gasoline, 93 AKI, with 7.15% ETOH - 2.7% Oxygen by weight.
14. Unleaded premium gasoline, 93 AKI, with 30% MTBE - 5.5% Oxygen by weight.
15. Unleaded premium gasoline, 93 AKI, with 12.4% MTHF - 2.7% Oxygen by weight.

TABLE 2. SAMPLE AIRCRAFT COMPONENTS USED DURING PHASE I TESTING.

1. O-Ring Seal - MS 29512
2. O-Ring Seal - NAS 1593
3. Gasket - AN 902
4. Gasket - AN 6290
5. Fuel Tank Bladder - BTC 54A
6. Fuel Tank Bladder - BTC 85
7. Fuel Tank Bladder - BTC 99
8. Hose - Stratoflex 124
9. Hose - MIL-H-6000B
10. Hose - Plumey Automotive Fuel Hose
11. Fuel Tank Material - Scaled Composites PTMW PR2032/~~PE3662~~
12. Fuel Tank Material - Scaled Composites Hexel 2410/~~XB4-38B~~
13. Fuel Tank Material - CO2 Development Corp. Safe T-Epoxy
14. Fuel Tank Material - Aluminum/Sloshing Compound

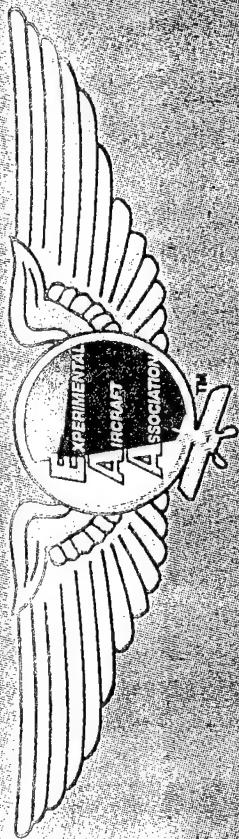


- The components tested were exposed to both high (175°F) and low (-65°F) temperatures
- Most of the materials did not show a statistically significant change compared to 100 LL to draw any conclusions from
- Materials exposed to fuels with Ethanol and Methanol did consistently show increased swelling and/or breakdown
- More extensive testing is needed including functional testing



GENERAL OBSERVATIONS EAA HAS RECOGNIZED

- **Use of automobile gasoline has been dependent on availability at the airport**
- **Many airports and FBO's have fought the use of automobile fuel or any other alternative fuel**
- **Pilots are conservative and slow to accept use of an alternative fuel**
- **Many aircraft owners and mechanics do not believe an aircraft engine can operate on an unleaded fuel**



-
- **EAA encourages others to try new alternative aviation fuels**
 - **EAA will continue to keep up with the changes in automobile gasoline**
 - **EAA is available to test fly new fuels that you may develop**

CONFERENCE SUMMARY

BOB HARRIS
DIRECTOR
NEBRASKA STATE ENERGY OFFICE
SUMMARIZED COMMENTS

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY

Bob Harris
Director
Nebraska State Energy Office
Conference Summary

Bob Harris, Director of the Nebraska Office of Energy, was given the job of summarizing the Conference. He started off by noting that he has been flying since 1964. [Saying that he can remember when the price of renting an airplane went from \$12/hour to \$14/hour and how that meant that he had to work 2 more hours for each hour of flying, since he was only making \$1/hour at the time.]

He then addressed the issue of commercializing alternative fuels in aviation, making the point that it is possible to accomplish significant objectives in a relatively short period of time. He pointed out that the Governors' Ethanol Coalition was only a concept 5 years ago, and it now has 19 governors. He also noted that the National Ethanol Vehicle Coalition is less than a year old, and has already raised over \$1 million.

He then turned to the issue of how to accomplish an aggressive commercialization strategy and said that having the conference in Texas makes it hard not to think about working together with the natural gas industry. "I have always thought that with the work going on in conversion of cellulosic biomass, the real winners are going to be the Southern States where the refineries which produce ETBE are located."

He pointed out that the ethanol industry shares other common ground with the natural gas industry, referring to a study that he had done which shows that Nebraska ethanol plants use \$36 million of natural gas per year. According to him, in the four years in which ethanol production in Nebraska went from 15 million gallons per year to 265 million gallons per year, natural gas use went from almost nothing to the \$36 million per year. He noted that this is the equivalent to placing 160,000 natural gas vehicles in use. (This study, "The Role of Natural Gas In Nebraska's Ethanol Industry And Opportunities For Other States" is attached.)

He also said that in Nebraska, they are learning to work with oil companies, and this cooperation is starting to payoff. Williams Pipeline Company has invested \$200 million in the ethanol industry. He went on to say, "We want to work with oil companies and natural gas companies, especially in the area of ETBE. We have the opportunity to work with them to develop a national RFG (reformulated gasoline) program."

He explained that the ethanol industry is supporting the idea of a national RFG program because this 49-state fuel would contain oxygenates, such as ETBE, MTBE or ethanol. The reason he mentioned the national RFG concept to the Conference was because he thought it might provide an example for a similar national program for aviation fuel such as jet fuel way down the trail.

He said that the national RFG program was a good example of how to build alliances, pointing out that because a national RFG program would allow car manufactures to raise the compression ratio of engines three points. (which would reduce the amount of gasoline used by cars with these engines by 10%) It could be the basis for building a very strong political alliance with the environmentalists and the auto companies.

Harris also described other ethanol industry concepts, such as "Fuels for America" (which would give incentives to domestic oil and gas and require a 3% domestic renewable content by the year 2002 or 2003) and "Fuels for the Heartland" (which is a separate program which would expand Minnesota's mandated use 2.7 - 7.7% oxygenate in the state's fuel supply throughout the Midwest

to all the Governors' Ethanol Coalition states), as examples of how alternative fuels in aviation could be commercialized.

Mr. Harris noted that he had flown down to the conference in a state aircraft with Ken Stevens, the Nebraska Aeronautics Director, which was proof that Nebraska is serious about possibly doing some of the things that Dr. Shauck has been promoting.

Bob Harris then went over a one-page commercialization strategy that he and Bill Holmberg had come up with (See attached) explaining, "We are just throwing out ideas for the commercialization of the aviation sector by 2005. It could be 2003 or 2000 whatever. Max will think that is way too long, but we didn't put in a [market] percentage [goal] there either."

After going over the points in Holmberg's commercialization strategy paper, Bob Harris asked John Russell, of DOE, to talk about the "Clean Airports" idea he had mentioned earlier in the Conference. John replied that he was not, yet, prepared to talk about it in any more detail. However, he said that he was willing to expand upon to the alternative aviation fuels hotline idea because he doesn't think it will cost any more money to implement.

According to Russell, the people now working at the DOE alternative fuels hotline would have to be provided with materials but, he noted, they are quick studies. "So there is very shortly going to be the aviation hot line. It will have the same number [as the DOE alternative fuels hotline]. The people there will, over the next six weeks, get better and better at answering the questions." John Russell concluded by saying "As to "Clean Airports", I don't want to answer any questions now. I promise some sort of two-pager on the subject before Christmas. It isn't that we can't do it. I want to do it right."

After John Russell's statement, Bob Harris said that he thinks that the "Clean Airports" idea has a lot of potential and suggested that in addition to aircraft fleets, it also involves the vehicles that are used for ground transportation at airports.

Harris closed by mentioning that there are 16.2 billion gallons of jet fuel used each year and noting that if 20% of that amount were replaced with ETBE, it would require 1.36 billion gallon of ethanol. He said once the ethanol industry realizes the actual dollars or the actual gallons of the potential, then they will come to you with money and support as they came to the National Ethanol Vehicle Coalition with \$1 million in one year.

**DRAFT COMMERCIALIZATION STRATEGY (WRITTEN COMMENTS WELCOME)
FOR
ALTERNATIVE AVIATION FUELS (AV-A) AND AVIATION ETHANOL (AV-E)**

MISSION: Commercialize Alternative Fuels in the Aviation Sector by the Year 2005.

PHASES

o Fuels:

- o** Ethanol
- o** Alcohols/Ethers, Ethers and Alcohol/Ether Blends
- o** ETBE/ethers in blends with jet fuel
- o** Natural Gas (LNG,CNG)
- o** Biodiesel

o Aircraft:

- o** Trainers
- o** Agriculture Aircraft
- o** General Aviation (Piston Engines)
- o** Turbo-pros and jets -- ethers

o Partnerships

Baylor, Texas State Technical College, Governors' Ethanol Coalition, State Agriculture, Energy and Aviation Departments, U.S. Departments of Energy, Agriculture and Transportation (FAA), National and State Corn Growers Associations, Agriculture Organizations and Groups and the ethanol industry.

ADVANCEMENT OF ETHANOL AND ETHERS IN AVIATION

- o** High Price of Av-Gas
- o** Phase out of leaded Av-Gas
- o** Competitive price of AV-E
- o** Growing availability of ethanol
- o** New basic industries and jobs
- o** Environmental benefits
- o** Reduced dependence on petroleum products

FINALIZE STRATEGIC PLAN

- o** Formation of ad hoc AV-E Advisory Committee
- o** Initiate development of needed funding
- o** Develop business plan and funding concepts/proposals
- o** Establish AV-E business enterprise
- o** Expand support staff to accelerate commercialization
- o** Announce creation of the AV-E Hotline and establishment of the AV-E information and Data Base as part of the Alternative Transportation Fuels Hot Line -- (800) 423-1363 (423 1DOE)
- o** Announce creation of the "Clean Airport" as an adjunct to the "Clean Cities" program managed by DOE. Include in the "Clean Airport" concept all ground and service vehicle as well as vehicles routinely transporting goods and passengers to airports such as taxis, motel/hotel vans etc.
- o** Support Alternative Aviation Fuels Air Shows
- o** Initiate planning for an International Alternative Aviation and Ground Support/Transportation Vehicles Show to be held in 1996 or 1997

Send comments to Dr. Max Shauck/Gracia Zanin, Department of Aviation Sciences, Baylor University, Box 97440, Waco, TX 76798

**THE ROLE OF NATURAL GAS
IN NEBRASKA'S ETHANOL INDUSTRY
AND OPPORTUNITIES FOR OTHER STATES**

TABLE OF CONTENTS

| | |
|---|---|
| Introduction | 1 |
| Nebraska's Ethanol Industry | 1 |
| Natural Gas in the Production of Ethanol | 1 |
| Direct Benefits | 2 |
| Indirect Benefits | 2 |
| Natural Gas Industry Direct Benefits of CNG | 2 |
| Natural Gas Indirect Benefits of CNG | 3 |
| Natural Gas in National Ethanol Industry | 3 |
| Ethyl Tertiary Butyl Ether | 3 |
| Ethanol Production | 4 |
| Summary | 4 |
| | |
| Tables | |
| Nebraska Ethanol Plants | 6 |
| United States Ethanol Plants | 7 |
| | |
| Appendix | |
| Natural Gas Production, Transmission and Consumption in Nebraska, 1992 | 9 |

Introduction

Over the past decade or so the pursuit of clean air and efforts to reduce our dependence on imported fuel through the development of alternative fuels have seemingly placed alternative fuels in competition with each other. Compressed natural gas and ethanol do compete as motor fuels. However, natural gas and ethanol are complementary in other important ways. Natural gas receives a net benefit from development of the ethanol industry since natural gas is the fuel of choice for production of ethanol in most states that will produce ethanol. The purpose of this paper is to illustrate the net benefit with reference to the development of Nebraska's ethanol industry and how natural gas can be used in other states to develop production of ethanol and co-products.

Nebraska's Ethanol Industry

There are currently three ethanol plants in operation in Nebraska with a combined capacity of 133.5 million gallons of ethanol (See Table I). Corn is the major feedstock with some milo used. All the plants use natural gas as fuel.

The industry is growing with an additional 110 to 120 million gallons of capacity under construction and scheduled to come on line early in 1995. An additional 30 million gallon plant by Ag Processing, Inc., not yet under construction, will bring the total capacity to 273.5 to 283.5 million by the end of 1995.

Value-added benefits to Nebraska resources is the primary purpose of all the operating and prospective ethanol plants in Nebraska. Corn ethanol is the primary product, although output includes joint products such as livestock feed, sweeteners known as corn fructose, corn syrup, carbon dioxide and other products. A typical bushel of corn used in a corn ethanol plant weighs 56 pounds. Most of the weight is from starch, oil, protein and fiber with some of it from natural moisture. The products that can be extracted from a bushel of corn are 31.5 pounds of starch or 33.0 pounds of sweetener or 2.5 gallons of fuel ethanol and 10.9 pounds of 21% protein feed and 2.6 pounds of 60% gluten meal and 1.6 pounds of corn oil.

Natural Gas in the Production of Ethanol

What net benefits does the natural gas industry receive from an expansion of the ethanol industry in Nebraska and other states? First, there is the direct benefit of sales of natural gas used for process steam and, in some cases, electricity to produce ethanol. Second, the natural gas industry receives an indirect benefit due to economic stimulus to the state's economy as the ethanol industry expands. In other words, a healthy state economy confers an important indirect benefit on the natural gas companies doing business within the state.

Direct Benefits. Nebraska's expanding ethanol industry *will be* fueled by natural gas. The natural gas industry could receive gross revenues of \$33 million to \$39 million when Nebraska's ethanol industry is in full production. At that time, 273.5 to 283.5 million gallons of ethanol will be produced annually. This ethanol output will require energy inputs of 36,000 to 41,000 Btus per gallon of corn ethanol.¹ For full production output, 98 million to 116 million therms of natural gas would be used. Given an average natural gas price for industrial use of 33.3 cents per therm, the ethanol industry would incur natural gas fuel costs of \$33 to \$39 million.²

Indirect Benefits. The natural gas companies which supply fuel to Nebraska's communities have a vested interest in maintaining the economic vitality of those communities. Expansion of the ethanol industry will stimulate the state economy in a number of ways. The increased demand for corn will bolster agricultural incomes. This effect is seen, not only in the increased quantity of corn used, but also corn prices. Generally, corn is five to ten cents a bushel higher in localities near ethanol plants.

There are also significant employment effects in nonagricultural sectors. It has been estimated that the employment effects of ethanol plants by 1995 will have been 3,072 temporary construction jobs, 515 continuing in-plant jobs and an indirect effect on employment of 1,870 continuing jobs.

Natural Gas Industry Direct Benefits of CNG. How do these benefits compare to those which might accrue to the natural gas industry if the same quantity of natural gas were used to fuel motor vehicles instead of producing ethanol? At an average price of 55 to 60 cents per therm for natural gas used as a motor fuel, the retail value of the natural gas would be \$54 million to \$70 million. It is unlikely that retail sales of compressed natural gas could come close to these figures until some time in the future. At present, there simply are not enough natural gas fueled vehicles to handle that volume of natural gas. The number of CNG fueled vehicles in the nation (federal and nonfederal) in 1994 has been estimated to be 12,300.³

¹Morris, David and Ahmed, Irshad, *How Much Energy Does it Take to Make a Gallon Ethanol?* (Washington, D.C.: Institute for Local Self-Reliance, 1992). Nationally the number of Btus used to produce a gallon of corn ethanol is 38,500. The literature further supports the notion that the Btu requirements for a gallon corn ethanol are likely to vary within a range of 36,000 and 41,000 Btus.

²A therm of natural gas contains 100,000 Btus. Converting the Btu requirements to therms gives 0.36 to 0.41 therms required per gallon of corn ethanol. The calculations are $0.36 \times 273.5 \text{ million gallons} = 98 \text{ million therms} \times 33.3 \text{ cents per therm} = \33 million and $0.40 \times 283.5 \text{ million gallons} = 116 \text{ million therms} \times 33.3 \text{ cents per therm} = \39 million .

³Department of Energy, Energy Information Administration, *Alternatives to Traditional Transportation Fuels An Overview*, (Washington, D.C.): U.S. Department of Energy, Energy Information Administration, 1994), 12-3.

Natural Gas Industry Indirect Benefits of CNG. The gasoline equivalents of the 98 and 116 million therms used to produce the corn ethanol are 78.4 million gallons and 92.8 million gallons.⁴ Assuming a passenger car is driven 12,000 miles a year at an average fuel efficiency of 25 miles per gallon, the same quantity of natural gas as used to produce the corn ethanol would fuel 163,333 to 193,333 natural gas vehicles for one year.

If there were enough CNG fueled vehicles to permit all of the natural gas used in Nebraska's ethanol production to be diverted to motor vehicle use, what would the order of indirect benefits be for the natural gas industry? This would involve expanding retail sales. It is unlikely that the economic stimulus of a given expansion at the retail level is as great as one at the manufacturing level. Expansion at the manufacturing level stimulates employment and incomes of suppliers of inputs used in production. Expansion of CNG use at the retail level would involve developing a refueling infrastructure. The cost of the refueling stations generally vary from \$100,000 to \$400,000.⁵ There would be a one-time job creation involved in the construction and some continuing employment with the refueling stations. Virtually all of the natural gas used in Nebraska (*see Appendix*) is imported into the state so there would be no economic stimulus to in-state suppliers of resources. There are additional costs to users of CNG either in the form of conversion costs ranging from \$2,700 to \$5,000 per vehicle or manufacturer's extra price premium of \$3,500 to \$7,500.⁶

Although the retail value of natural gas as a motor vehicle fuel is greater than its value in industrial uses, it must be recognized that additional costs of distribution would be incurred (even if it were in place) and the profit margins of retailing are generally less than for manufacturing. The distribution system for fueling infrastructure for compressed natural gas is largely undeveloped. The distribution system for natural gas for industrial uses is already in place.

Natural Gas in the National Ethanol Industry

ETBE. The provision that reformulated gasoline must be used in nine of the nation's largest non-attainment cities has done much to spur the demand for ethanol. Ethyl tertiary butyl ether (ETBE) is one of the oxygenates that can be used in reformulated gasoline. Ethanol is teamed again with natural gas in its production. In producing ETBE, isobutylene--a common derivative of natural gas liquids--is reacted with ethanol over heat in the presence of a catalyst.

⁴ The Btu content of one therm of natural gas is the equivalent of 0.8 gallon of gasoline.

⁵ Department of Energy, *Assessment of Costs and Benefits of Alternative Fuels within the U. S. Transportation Sector*, ([Washington, D.C.]: U.S. Department of Energy, 1990).

⁶ Department of Energy, Argonne National Laboratory, *Taking an Alternative Route*, ([Washington, D.C.]: U.S. Department of Energy, Argonne National Laboratory, 1994), 23.

One gallon of ethanol combines with 193 million Btus of natural gas liquids to produce 2.5 gallons of high octane ETBE. Each gallon of ETBE can replace 0.84 gallons of gasoline produced from crude oil. The production of ETBE allows the nation's two most abundant domestic clean burning fuels--natural gas and ethanol--to be used in the same gallon of gasoline without engine modification.

ETBE also provides excellent environmental and performance benefits. The addition of ETBE to gasoline significantly reduces Reid vapor pressure. This reduces emissions of volatile organic compounds, precursors to ozone. By the year 2000, reformulated gasoline must reduce emissions of nitrogen oxides relative to the 1990 baseline gasoline. ETBE can accomplish a reduction in automobile emissions of nitrogen oxides because it reduces the aromatic content of motor fuels and increases the octane of fuels.

Ethanol Production. Current production of corn ethanol stands at 1.402 billion gallons. This uses 539 million bushels of corn. By mid-1995 production of corn ethanol will have increased to 1.645 billion gallons of ethanol which will use 633 million bushels of corn.⁷

Table 2 is a tabulation by state of all the ethanol plants in the United States. The range of plant sizes as well as the variety of feedstocks and fuels used are noteworthy. Ethanol is being made from industrial wastes such as cheese whey, potato waste and brewery waste as well as corn, milo, and other agricultural grain crops.

Although a variety of fuels are present in Table 2, according to industry sources natural gas is the fuel of choice, with new plants opting for natural gas and some online plants switching from coal to natural gas as their main fuel.⁸ Natural gas is a clean fuel. It is abundant and relatively inexpensive, and in many states it is the low-cost fuel for producing ethanol from a variety of feedstocks. Table 2 shows that natural gas is used as a fuel for plants of varying sizes. This is a reflection of its versatility and adaptability.

According to Larry Johnson of the Minnesota Ethanol Commission, it takes a large and expensive boiler to justify coal as a fuel. Projects are going to natural gas even though they are in coal producing states. Natural gas is abundant and can provide a low cost means of producing ethanol from a variety of feedstocks.

Summary

This paper has briefly described Nebraska's ethanol industry as being complementary to the natural gas industry. Natural gas is the fuel of choice in many ethanol plants and will

⁷Correspondence, National Corn Growers Association, October 31, 1994.

⁸Correspondence from Information Resources, Inc. November 1994.

be in new ethanol producing states. It is a clean fuel and can be used in plants of varying sizes.

Expansion of Nebraska's ethanol industry has benefited the natural gas industry through increased sales of gas for industrial use and in maintaining a strong state economy which benefits the marketing of various natural gas products. Direct benefits to the natural gas industry as the Nebraska's ethanol grows are impressive. When all plants which are currently under construction and planned are in full operation gross revenues to the natural gas industry will be \$33 to \$39 million. The same revenue could not be realized from sales of compressed natural gas for motor vehicle fuel. The major reason is that there simply are not enough natural gas fueled vehicles to handle that volume of natural gas. It would take about 163,333 to 193,333 natural gas vehicles to consume 98 to 116 million therms of natural gas used to produce Nebraska's corn ethanol. At present there are only 12,300 motor vehicles fueled by compressed natural gas.

It was pointed out that the ethanol and natural gas industries are complementary. Growth of the ethanol industry carries strong economic benefits to the natural gas industry. One of the sources of growth is simply the increased demand for ethanol for use in ETBE. The environmentally beneficial properties of ETBE which include the lowering of Reid vapor pressure, volatile organic compounds and nitrogen oxides are reasons for the increased demand for ethanol and natural gas liquids. The use of ETBE as an oxygenate in reformulated gasoline will have substantial impact on both the ethanol and natural gas industries.

All of this should not be interpreted as saying that the market for compressed natural gas should not be expanded. It should. We need a variety of alternative fuels. Nebraska needs to have a full complement of fueling facilities for each fuel so that motorists can use alternative fuels effectively.

Table 2

ETHANOL PLANTS IN THE UNITED STATES
November 1994

| <u>State/Company</u> | <u>Location</u> | <u>Capacity</u> | <u>Planned Expansion</u> | <u>Feedstock</u> | <u>Fuel</u> |
|-------------------------------|-----------------|-----------------|------------------------------|-----------------------------------|-------------|
| California | | | | | |
| Golden Cheese of California | Corona | 2,600,000 | | cheese whey | steam |
| Parallel Products | Cucamonga | 2,600,000 | | food & beverage industry waste | |
| Dairymen's Cooperative | Tulare | 700,000 | | cheese whey | steam |
| Idaho | | | | | |
| J. R. Simplot Company | Caldwell | 4,000,000 | | potato waste | steam |
| J. R. Simplot Company | Burly | 3,000,000 | | potato waste | steam |
| Illinois | | | | | |
| ADM | Decatur | 330,000,000 | | corn | coal |
| ADM | Peoria | 200,000,000 | | corn | coal |
| Pekin Energy Co. | Pekin | 100,000,000 | | corn | coal |
| Midwest Grains Products, Inc. | Pekin | 12,000,000 | | corn | coal |
| Vienna Correctional Ctr. | Vienna | 500,000 | | corn | coal |
| Indiana | | | | | |
| New Energy Co. of Indiana | South Bend | 75,000,000 | | corn | coal |
| Iowa | | | | | |
| ADM | Cedar Rapids | 170,000,000 | | corn | coal |
| | Clinton | 140,000,000 | | corn | coal |
| Cargill | Eddyville | 30,000,000 | | | |
| Hubinger Co. | Keokuk | 18,000,000 | | corn | |
| Grain Processing Corp | Muscatine | 10,000,000 | | corn | natural gas |
| Manildra Energy, Inc. | Hamburg | 6,000,000 | | corn | coal |
| Kansas | | | | | |
| High Plains Corporation | Colwich | 20,900,000 | | other feedgrain | natural gas |
| Reeve Agri Energy, Inc. | Garden City | 7,500,000 | | corn | natural gas |
| Midwest Grain Products, Inc. | Atchison | 6,000,000 | | other feedgrain | natural gas |
| ESE Alcohol, Inc. | Leoti | 500,000 | | milfo/corn | natural gas |
| Minnesota | | | | | |
| Minnesota Corn Processors | Marshall | 32,000,000 | | corn | coal |
| Morris Ag-Energy Co., Inc. | Morris | 4,500,000 | 10,500,000 | corn | natural gas |
| Kraft, Inc. | Melrose | 1,200,000 | | cheese whey | |
| Minnesota Clean Fuels | Dundas | 1,200,000 | | ? | ? |
| Montana | | | | | |
| Alcotach, Inc. | Ringling | 2,000,000 | | wheat | wood |

| | | | | | | |
|-----------------------------|-------------|------------|------------|---------------|------------------------------|----------------------|
| Nebraska | | | | | | |
| Minnesota Corn Processors | Columbus | 70,000,000 | | corn | natural gas | |
| High Plains Corporation | York | 35,000,000 | | corn | natural gas | |
| Chief Ethanol Fuels, Inc. | Hastings | 28,500,000 | 15,000,000 | corn/milo | natural gas | |
| Nebraska Nutrients, Inc. | Sutherland | 15,000,000 | | corn | natural gas | (under construction) |
| Cargill | Blair | 70,000,000 | | corn | natural gas | (under construction) |
| Nebraska Energy Cooperative | Aurora | 25,000,000 | | corn/milo | natural gas | (under construction) |
| Ag Processing | Hastings | 30,000,000 | | corn | natural gas | (to be constructed) |
| New Mexico | | | | | | |
| Giant Refining, Inc. | Portales | 12,000,000 | 2,500,000 | grain sorghum | electricity & natural gas | |
| North Dakota | | | | | | |
| ADM | Walhalla | 16,000,000 | | corn | natural gas | |
| Alchem Limited | Grafton | 12,000,000 | | corn | coal/propane | |
| Ohio | | | | | | |
| South Point Ethanol | South Point | 65,000,000 | 10,000,000 | corn | coal | |
| South Dakota | | | | | | |
| Heartland Grain Fuels | Aberdeen | 5,000,000 | | corn | natural gas | |
| Broin Enterprises, Inc. | Scotland | 6,000,000 | | corn | propane | |
| Tennessee | | | | | | |
| A.E. Staley Mfg. Co. | Loudon | 40,000,000 | 20,000,000 | corn | coal | |
| Washington | | | | | | |
| Georgia Pacific Corporation | Bellingham | 3,500,000 | | waste | natural gas | |
| Pabst Brewing Company | Olympia | 700,000 | | brewery waste | natural gas | |

Source: Information Resources, Inc., Nebraska Energy Office.

APPENDIX

NATURAL GAS PRODUCTION, TRANSMISSION AND CONSUMPTION IN NEBRASKA, 1992

This appendix contains information on the production and consumption of natural gas in Nebraska. The data are from *Energy Information Administration/Natural Gas Annual 1992, Volume 1 and Volume 2*.

Virtually all of the natural gas consumed in Nebraska is imported. In 1992, 107 billion cubic feet of natural gas were used in Nebraska and less than one percent of this--1 billion cubic feet--was produced in Nebraska. This is shown in Table A-1.

Net interstate movements of natural gas are shown in Figure A-1. In 1992, 913 billion cubic feet of natural gas, including domestic production, came into the state. Of this, 790 billion cubic feet were shipped out of state. Since Nebraska contains major pipelines, it serves as a conduit for natural gas going to other states.

**Natural Gas Production, Transmission, and Consumption by State,
1967-1992 (Continued)**
(Million Cubic Feet)

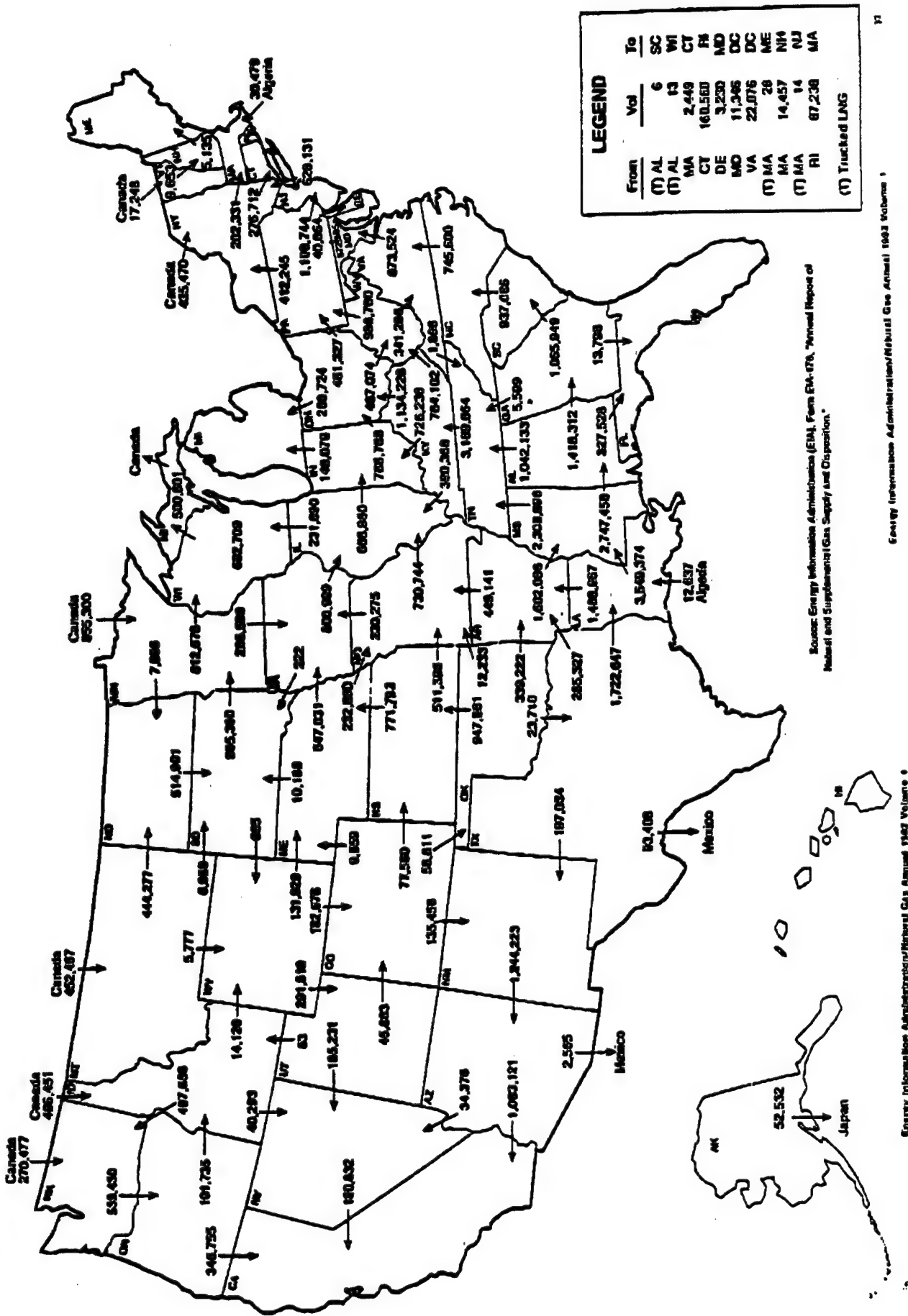
| State | Marketed Production | Extraction Loss | Balancing Item | Net Interstate Movements | Net Move- ments Across U.S. Borders | Net Storage Changes | Supplemental Gas Supplies | Consumption |
|----------------|------------------------|-----------------|-----------------|--------------------------------|---|---------------------------|---------------------------------|-------------------|
| 1992 | | | | | | | | |
| Alabama | 255,098 | 8,490 | -30,213 | -40,838 | 0 | 239 | 171 | 278,794 |
| Alaska | 443,597 | 22,004 | 84,090 | 0 | -82,532 | 0 | 0 | 383,121 |
| Arizona | 771 | NA | 4,718 | 125,729 | -2,568 | 0 | 0 | 129,550 |
| Arkansas | 202,479 | 413 | -20,293 | 42,289 | 0 | -518 | 0 | 224,576 |
| California | 385,632 | 12,386 | 38,452 | 1,810,708 | 0 | -28,158 | 0 | 2,030,564 |
| Colorado | 323,041 | 18,149 | -13,191 | -50,647 | 0 | -4,860 | 7,158 | 253,073 |
| Connecticut | NA | NA | -7,691 | 118,601 | 0 | -355 | 40 | 111,205 |
| Delaware | NA | NA | -1,596 | 37,634 | 0 | -5 | 3,665 | 38,808 |
| D.C. | NA | NA | -465 | 33,482 | 0 | 0 | 0 | 32,957 |
| Florida | 6,657 | 2,593 | 7,573 | 841,325 | 0 | 0 | 0 | 352,992 |
| Georgia | NA | NA | 8,647 | 332,967 | 0 | 16 | 168 | 342,665 |
| Hawaii | NA | NA | -16 | NA | NA | 0 | 2,711 | 2,693 |
| Idaho | NA | NA | -7,330 | -440,253 | 488,451 | -47 | 0 | 48,915 |
| Illinois | 347 | 100 | -44,669 | 1,021,441 | 0 | -8,387 | 8,042 | 993,428 |
| Indiana | 174 | NA | -1,733 | 480,369 | 0 | -1,179 | 3,507 | 483,498 |
| Iowa | NA | NA | -12,634 | 842,076 | 0 | -3,846 | 45 | 230,932 |
| Kansas | 958,007 | 42,723 | -32,874 | -257,668 | 0 | -18,486 | 0 | 343,217 |
| Kentucky | 79,890 | 2,342 | -55,636 | 174,733 | 0 | 6,573 | 5 | 189,877 |
| Louisiana | 4,914,300 | 132,566 | 33,706 | -3,295,894 | 12,637 | -13,511 | 0 | 1,545,604 |
| Maine | NA | NA | -89 | 6,181 | 0 | 4 | 0 | 6,131 |
| Maryland | 23 | NA | -10,559 | 192,422 | 0 | 422 | 125 | 181,300 |
| Massachusetts | NA | NA | -10,049 | 272,822 | 30,479 | -1,844 | 105 | 295,001 |
| Michigan | 194,815 | 8,099 | 68,603 | 1,129,512 | -309,301 | -2,251 | 14,694 | 861,181 |
| Minnesota | NA | NA | 35,458 | -881,763 | 855,306 | 256 | 52 | 208,821 |
| Mississippi | 91,697 | 418 | 54,787 | 96,107 | 0 | 1,732 | 0 | 253,442 |
| Missouri | 27 | NA | -3,927 | 244,930 | 0 | -16 | 0 | 240,745 |
| Montana | 53,967 | 907 | -19,444 | -467,084 | 452,467 | -12,602 | 0 | 45,581 |
| Nebraska | 1,177 | 3 | -18,422 | 123,182 | 0 | 517 | 1,437 | 106,853 |
| Nevada | 30 | NA | -10,782 | 79,087 | 0 | -71 | 30 | 68,476 |
| New Hampshire | NA | NA | -2,219 | 18,975 | 0 | 0 | 96 | 16,852 |
| New Jersey | NA | NA | 81,223 | 480,827 | 0 | -48 | 14,382 | 546,260 |
| New Mexico | 1,266,553 | 73,320 | -83,782 | -911,739 | 0 | -5,057 | 0 | 202,875 |
| New York | 23,508 | NA | -80,558 | 581,333 | 435,470 | 1,842 | 1,190 | 959,004 |
| North Carolina | NA | NA | -11,955 | 181,486 | 0 | -92 | 2 | 179,595 |
| North Dakota | 54,553 | 6,055 | -7,996 | -62,738 | 0 | 0 | 58,498 | 26,588 |
| Ohio | 144,815 | 72 | 4,785 | 643,899 | 0 | -15,572 | 1,051 | 810,121 |
| Oklahoma | 2,017,386 | 164,609 | -112,482 | -1,286,616 | 0 | -10,058 | 0 | 642,827 |
| Oregon | 2,580 | NA | 27,923 | 90,840 | 0 | -604 | 2 | 122,350 |
| Pennsylvania | 136,875 | 604 | -28,877 | 578,240 | 0 | 5,946 | 132 | 652,521 |
| Rhode Island | NA | NA | 2,935 | 73,222 | 0 | -420 | 155 | 77,833 |
| South Carolina | NA | NA | 9,179 | 128,568 | 0 | 16 | 25 | 138,057 |
| South Dakota | 1,458 | NA | -1,036 | 25,225 | 0 | 11 | 10 | 28,645 |
| Tennessee | 1,770 | 0 | 70,754 | 189,980 | 0 | -306 | 12 | 241,702 |
| Texas | 8,146,632 | 374,138 | -64,200 | -2,181,287 | -93,408 | -43,441 | 1 | 3,478,274 |
| Utah | 171,293 | 11,851 | -62,633 | 60,343 | 0 | 4,482 | 0 | 122,649 |
| Vermont | NA | NA | 3 | -6,883 | 17,248 | 0 | 3 | 7,901 |
| Virginia | 24,733 | NA | -14,334 | 189,401 | 0 | 0 | 245 | 200,039 |
| Washington | NA | NA | -65,652 | -51,772 | 270,477 | -8,137 | 180 | 189,161 |
| West Virginia | * 182,000 | 9,436 | 25,017 | -76,901 | 0 | -8,180 | 0 | 128,861 |
| Wisconsin | NA | NA | -20,181 | 351,672 | 0 | -89 | 1 | 331,581 |
| Wyoming | 542,578 | 31,378 | -110,627 | -585,581 | 0 | -8,538 | 0 | 123,547 |
| Total | 18,711,808 | 871,905 | -507,585 | 0 | 1,921,225 | -172,882 | 117,919 | 18,544,364 |

- * Data for the District of Columbia are included with data for Maryland.
- * Data for New Hampshire and Vermont are included with data for Maine.
- NA = Not available.
- * = Revised data.

Sources: Energy Information Administration (EIA), Form EIA-178, "Annual Report of Natural and Supplemental Gas Supply and Disposition"; Form EIA-827, "Annual Quantity and Value of Natural Gas Report"; Form EIA-857, "Monthly Report of Natural Gas Purchases and Deliveries to Consumers"; Form EIA-816, "Monthly Natural Gas Liquids Report"; Form EIA-739, "Monthly Power Plant Report"; Forms EIA-181/PERC-8, "Underground Gas Storage Report"; Form FPC-14, "Annual Report for Importers and Exporters of Natural Gas"; Form EIA-54A, "Annual Report of the Origin of Natural Gas Liquids Production"; and the U.S. Minerals Management Service.

Figure A-1.

Interstate Movements of Natural Gas in the United States, 1988
(Billion Cubic Feet)



ADDRESS AT EVENING RECEPTION

**ANDRES ZELLWEGER
DIRECTOR
OFFICE OF AVIATION RESEARCH
FEDERAL AVIATION ADMINISTRATION**

**FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE
AVIATION FUELS
NOVEMBER 2-4 1995
BAYLOR UNIVERSITY**

Address at the Dinner Reception
Dr. Andres Zellweger
Director of Aviation Research
FAA

I would like to start and really recognize Max Shauck. He is, in my view, a true pioneer and I really admire the energy and enthusiasm he has for the business he is in. I think the success of this conference is a tribute to his dedication and I am really proud to be part of what I hope is the first of many international conferences on alternative aviation fuels.

I have to warn you, when I was asked to come here I told my family and they laughed because they said, "Dad, you know, you're kind of a serious person and when we tell jokes they go right over your head. People who speak after dinner are supposed to be kind of funny." They tell me that I have no sense of humor. So, I'll try to do my best tonight and not bore you with jokes that bomb.

I do have kind of a message I want to get across to you, but I will try to be brief because you are having so much fun.

I wanted to say one quick thing before I start talking about the message I have for you. We started something in FAA this summer, an initiative by our administrator called "Challenge 2000". We are trying to posture ourselves for what is needed for certification in the next century. And, I was thinking, one of the things I heard today -- several times -- is problems you have with certification. If any of you have ideas on how we can improve engine certification, I really wish you would give me a call or write to me in the next few weeks.

I learned a lot today and I was pleased to see so many students at the meetings as well. I think that it is great to see young kids come to learn and to hear what you, the experts, have to say. I am not sure if they were there because they are interested or if Max said it was a requirement for your course.

I am here today because I really think that aviation gas and alternative fuels are very important to us here in the aviation field. It is also very important to our Administrator David Hinson. I have spoken to him about this before. He writes letters to presidents of engine companies to encourage them to do work. He has asked us to put together aviation gas brochures for Oshkosh and the like.

But, the point is we are not investing a lot of money at FAA in aviation fuels. I think it is not because we don't think it is important. But I think it is the reality of the fact that federal research budgets are shrinking today and we have to face that. The FAA budget for research was \$270 million dollars last year. This year it is down by 30% to \$185 million and that is happening across the government. All the budgets are going down.

So, what can we do? We in FAA are trying to be much smarter about our investment strategies. Our funding decisions are based on looking to see if what we put money into is consistent with our goals. We look at risks, costs, benefits. We look at whether other people might do something similar. An important thing that we look at is, if our research is successful, whether we can do something with it. That is really critical. If we build a new air traffic control system in the lab, do we have the money to implement it. Are the users going to want it?

The other thing that we are doing is we are working much harder to build partnerships with other organizations. FAA's research is now much stronger in our relationship with NASA for example. We pool our moneys and do joint research. We work with the Defense Department and with industry, and with foreign governments. We have to do leveraging, I think.

What does that mean to all of you? I think the message I am giving you is, "there is not going to be that much money from the federal government to implement what you want." But, I heard today that there is a great deal of enthusiasm. I heard at lunch today that the states are willing to invest moneys. That there is the opportunity for entrepreneurs who can put money into the kinds of things that are needed to make aviation fuel, unleaded Avgas and alternative aviation fuels a reality.

I think that if you work internationally that is a big plus. We had a big session on that, this afternoon, and I am really encouraged by it. The other important thing that I would encourage all of you to do is to "think about the next steps."

Many of you are working on demonstrations, on research and the like. You need to think about what needs to be done and what can you do if you are successful. Think about it before you do the work. Because, the kinds of research you do, the kinds of demonstrations you want to have, ought to be ones that can be implemented later on, or you are wasting your time in a way.

I think you all need to go back to have more fun, so let me try to close. But, I want to close with something very very important I learned recently. I was talking to a professor from Stanford and he explained to me a new law. It's called Cannon's Law of Consequences. It's named after Bob Cannon, who is the Chairman of the Aerospace Department at Stanford.

Now, Cannon's Law of Consequences is very important because it explains to us why everything happens. Imagine, if you know why everything happens you really know a lot. Well, Cannon's Law of Consequences is very simple, it says, "One thing leads to another."

I believe that. I thought about it and it is really true. That's why things happen. One thing leads to another. My message to all of you is, that I think if you worry about how you can effect that one thing that leads to the next thing, to the next thing. You can really be successful in making a reality out of those things which you are after. I think you can make alternative fuels a reality in the world.

Thank you.

CLEAN AIRPORTS PROGRAM

During the *International Conference on Alternative Aviation Fuels*, John Russell, Director of the Office of Alternative Fuels at the U.S. Department of Energy, proposed the establishment of a Clean Airports program to promote the use of alternative fuels in the aviation sector.

DOE is considering the following factors as criteria for designation as a Clean Airport:

- Identify potential stakeholder organizations or individuals that would implement the Clean Airports program,
- Establish an organizational structure to oversee and implement the Clean Airports program,
- Develop an implementation plan to fulfill the goals of the Clean Airports program,
- Develop a Memorandum of Understanding (MOU),
- Establish a base for alternative fuel aircraft (minimum requirements may apply),
- Establish refueling infrastructure for alternative fueled aircraft, and
- Provide a mechanism to educate the public about alternative fuels.

For more information on the Clean Airports program, call the U.S. Department of Energy's National Alternative Fuels Hotline at 1-800-423-1DOE (1363).

FIRST INTERNATIONAL CONFERENCE ON ALTERNATIVE AVIATION FUELS

REGISTRATION LISTING *(ALPHABETICAL BY COMPANY)*

NOVEMBER 2-4, 1995

**BAYLOR UNIVERSITY
AVIATION SCIENCES DEPARTMENT
P.O. BOX 97413
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